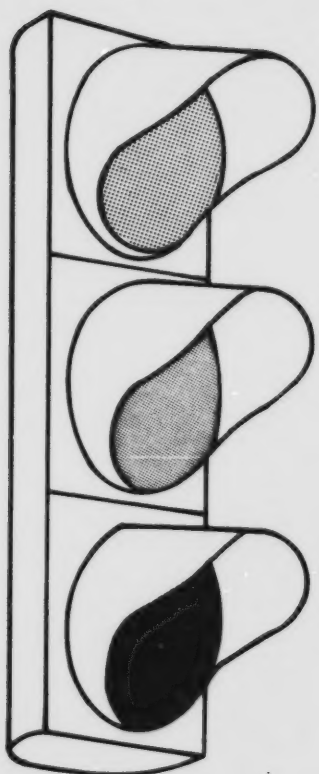




TRAFFIC SIGNALS

**Left Turn Phasing
and Displays**

**Vehicle Clearance
Intervals**

Flashing Operation

STATE-OF-THE-ART

**PREPARED FOR THE
TRANSPORTATION DEVELOPMENT CENTRE**

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MARCH 1984

TP# 5324E

**TRAFFIC SIGNALS
LEFT TURN
PHASING AND DISPLAYS
VEHICLE CLEARANCE INTERVALS
FLASHING OPERATION
STATE-OF-THE-ART**



by
Keith G. Mclean
Chief Traffic Engineer
DeLCan (De Leuw Cather, Canada Ltd.)

March 1984

The contents of this report reflect the views of the contractor and not necessarily the official views or policies of the Transportation Development Centre of Transport Canada.

PROJECT TEAM

The project was undertaken by the following DeLCan staff:

Mr. Keith G. McLean, P.Eng., Project Director
Mr. Michel Gravel, Ing., Project Manager
Mr. R.K. Orchin, P.Eng., Project Engineer

Assistance to the Project Team was provided by:

Ms. Lorelee Birch
Ms. Wendy Davidson

ACKNOWLEDGEMENTS

The Consultants would like to acknowledge the assistance provided by the members of the Council on Uniform Traffic Control Devices for Canada, Technical and Research Committee Study Group for this project whose names appear in Section I of the report. As well the assistance of

Mrs. Ling Suen; Senior Special Advisor, Transportation Development Centre, Transport Canada

Ms. Catherine Hirou; Project Officer, Transportation Development Centre, Transport Canada

is gratefully acknowledged.

The Study Team has been fortunate in receiving excellent cooperation from a number of persons with governmental and professional organizations in the United States of America. The names of those persons also appear in Section I of the report.

REPORT DOCUMENTATION FORM

1. Transport Canada Report No. TP 5324E	2. TDC Project No. 4780	3. Recipient's Catalogue No.	
4. Title and Subtitle Traffic Signal Left-Turn Phasing and Displays, Vehicle Clearance Intervals, Flashing Operation: State-of-the-Art		5. Report Date March 1984	
		6. Performing Organization Report No. 04-1316A-00	
7. Author(s) K.G. McLean, P.Eng. et al		8. Transport Canada File No. D1465-307-3	
9. Performing Organization Name and Address De Leuw Cather Canada Ltd. 2315 Riverside Drive, Billings Bridge Plaza P.O. Box 8004 Ottawa, Ontario K1G 3H6		10. DSS File No.	
		11. DSS or Transport Canada Contract No. 4780	
12. Sponsoring Agency Name and Address Transportation Development Centre (TDC) 1000 Sherbrooke Street West Suite 2421 Montreal, Quebec H3A 2R3		13. Type of Report and Period Covered Phase I Final; 12/82 - 03/84	
		14. Sponsoring Agency Code TDC 4780	
15. Supplementary Notes		16. TDC Project Officer L. Suen	
17. Abstract This document provides the results of a literature review, contact with persons and organizations in the U.S.A. and a survey of practice of municipal and provincial road authorities across Canada with respect to left-turn phasing and displays, clearance intervals and flashing operation of traffic signals. Also included is a review of the relevant portions of provincial statutes dealing with traffic signals as obtained from a study undertaken by the Roads and Transportation Association of Canada and the Canadian Conference of Motor Transport Administrators. The report was prepared to assist the Canadian Council on Uniform Traffic Control Devices in the development of uniform standards for the application of practices and devices in the foregoing aspects of the use of traffic signals.			
18. Key Words Traffic Signals, Left-Turn Signals, Vehicle Clearance Intervals, Flashing Operation		19. Distribution Statement Available upon request from Transportation Development Centre	
20. Security Classification (of this report) Unclassified	21. Security Classification (of this page) Unclassified	22. No. of Pages	23. Price Nil

FORMULE DE DOCUMENTATION POUR RAPPORT

1. N° du rapport Transports Canada TP 5324E	2. N° de l'étude — CDT 4780	3. N° de catalogue du destinataire	
4. Titre et sous-titre Traffic Signal Left-Turn Phasing and Displays, Vehicle Clearance Intervals, Flashing Operation: State-of-the-Art		5. Date du rapport mars 1984	
		6. N° du rapport de l'organisme exécutant 04-1316A-00	
7. Auteur(s) K.G. McLean, P.Eng. et al		8. N° de dossier Transports Canada D1465-307-3	
9. Nom et adresse de l'organisme exécutant De Leuw Cather Canada Ltée 2315 Riverside Drive, Billings Bridge Plaza C.P. 8004 Ottawa, Ontario K1G 3H6		10. N° de dossier — ASC	
		11. N° de contrat — ASC ou Transports Canada 4780	
12. Nom et adresse de l'organisme parrain Centre de développement des transports (CDT) 1000 ouest, rue Sherbrooke Suite 2421 Montréal, Québec H3A 2R3		13. Genre de rapport et période visée Phase I Final; 12/82 - 03/84	
		14. Code de l'organisme parrain CDT 4780	
15. Remarques additionnelles		16. Agent de projet — CDT L. Suen	
17. Résumé Ce rapport présente les résultats d'une étude concernant les pratiques actuelles en régulation du trafic automobile urbain, notamment en ce qui concerne la priorité de virage à gauche et la signalisation correspondante, la programmation des feux et leur mise au clignotant. Les chercheurs ont procédé par voie de recherche documentaire, de consultations auprès des spécialistes et organisations intéressés des Etats-Unis et aussi par une enquête auprès des administrations municipales et ministères provinciaux de la voirie du Canada. Ce rapport reprend également les résultats d'une autre étude, réalisée sous l'égide de l'Association des routes et transports du Canada et de la Conférence canadienne d'administrateurs en transport motorisé, portant sur les chapitres des statuts provinciaux traitant de la signalisation routière et des feux de circulation. Le CDT a parrainé cette étude pour assister le Conseil canadien de normalisation des dispositifs de régulation de la circulation dans l'élaboration d'une norme nationale concernant les pratiques et appareils de régulation à mettre en oeuvre à l'échelle du pays et notamment sous les aspects mentionnés plus haut.			
18. Mots-clés Feux de circulation, priorité de virage à gauche, signalisation, programmation des feux, mise au clignotant		19. Diffusion Disponible sur demande auprès du Centre de développement des transports	
20. Classification de sécurité (de ce rapport) Non-classifié	21. Classification de sécurité (de cette page) Non-classifiée	22. Nombre de pages	23. Prix aucun

TABLE OF CONTENTS

	<u>PAGE</u>
1.0 INTRODUCTION	1
2.0 LITERATURE REVIEW	8
2.1 Summary of Selected References Left-Turn Phasing and Displays	8
2.2 Summary of Selected References Vehicle Clearance Timing	31
2.3 Summary of Selected References Flashing Operation of Traffic Signals	40
3.0 SUMMARY OF RESPONSES TO QUESTIONNAIRE	47
3.1 Basis for Determining the Need for a Left-Turn Phase (Question 1A)	47
3.2 Method Used to Determine Left-Phase Time (Question 1B)	47
3.3 Portion of "Advanced Green" Left-Turn Phase Dedicated to a Clearance Interval (Question 1C)	47
3.4 Type of Left-Turn Phasing Used and Guidelines Applied in the Selection of the Type of Phasing (Question 1D)	48
3.5 Vehicle Clearance Interval Determination (Question 2A)	48
3.6 Use of "All-Red" Vehicle Clearance Interval (Question 2B)	48
3.7 Flashing (Red-Amber) Operation of Traffic Signals (Question 3)	48
4.0 RULES OF THE ROAD	54

1.0 INTRODUCTION

In 1982, the Roads and Transportation Association of Canada (RTAC) requested of its membership an indication of the major technical areas of greatest concern. At its meeting in Halifax in September, 1982, the Traffic Operations Management Committee and its Traffic Operations Technical Committee reviewed the list compiled by RTAC and placed the following subject areas in a group representing the highest priority in need of research and development:

- . standardization of signal displays and phasing
- . vehicle clearance intervals
- . left-turn phasing and capacity
- . standardization of left-turn movement traffic signal indicators.

The foregoing subject areas were consolidated and a project entitled "Standardization of Signal Displays and Operation" was selected for recommendation to the Traffic Operations Management Committee for consideration. Two other projects, one of which related to sign illumination and reflectorization and the other of which related to cost-effective road markings, were also recommended to the Traffic Operations Management Committee for consideration. These three projects were presented to Technical Council by the Chairman of the Traffic Operations Management Committee as those being the highest in priority of need for research and development.

Responsibility for the development of a prospectus for the project on the "Standardization of Signal Displays and Operation" was assigned to K.G. McLean, P.Eng., Chief Traffic Engineer, DeLCan, Consulting Engineers.

In the course of preparing the prospectus, discussions were held with the Transportation Development Centre of Transport Canada to determine the possibility of obtaining financial assistance in undertaking the necessary research in this area. The Transportation Development Centre expressed considerable interest, particularly if the project could be undertaken within a reasonably short time and if positive action could be taken which would benefit practicing traffic engineers by bringing about a standardization of signal displays and the application of uniformity in traffic signal timing and phasing particularly for left-turn movements.

Accordingly discussions were held with Mr. Andre Lemire, Chairman of the Council on Uniform Traffic Control Devices, Mr. Bruce Elliott, Chairman of the Transportation Operations Management Committee, Mr. John Robinson, Director of Technical Services of RTAC and Mrs. Ling Suen of the Transportation Development Centre. Agreement was reached on a two-phase study as follows:

- Phase 1 to include a literature review, contact with appropriate persons/groups in the United States and a questionnaire survey in order to determine current Canadian practices.
- Phase 2 to be the development of recommended standards and practices for determining the need for left-turn phasing and vehicle clearance

intervals in traffic signal operations as well as standardized displays for traffic signal indications for these purposes.

Authority to proceed with Phase 1 of the project was provided by the Transportation Development Centre on January 28, 1983.

This report presents the findings of Phase 1 of the project. As a result of the contacts with appropriate persons/groups in Canada and the United States a considerable amount of literature was identified. The results of the literature review are discussed in Section 2. In Section 3 the results of the extensive questionnaire survey are presented.

Section 4 contains a summary of relevant provincial legislation as obtained from a Canadian Conference of Motor Transport Administrators publication of September 1982.

The appendices to this document contain lists of selected references, a copy of the questionnaire used in the survey of practice, a tabulation of the responses to the questionnaire and a summary of the rules of the road as contained in provincial statutes as these relate to traffic signals.

Throughout the project, and this report, terminology is used which, in order to ensure consistency, conforms to the following definitions.

General

1. Permissive Left Turns

The left turn driver has the opportunity to turn, permissibly, when adequate gaps appear in opposing traffic. The driver must yield the right-of-way to opposing vehicular and pedestrian traffic.

2. Protected Left Turns

The left turn driver is directed to turn left in a protected manner through a signal display and left turn traffic has the right-of-way over the opposing vehicular and pedestrian traffic.

Protected/Permissive Left Turn Phasing

The left turn driver is first directed to turn left in a protected manner through a signal display and then given the opportunity to turn, permissibly, when adequate gaps appear in opposing traffic, through the display of a circular green. This can be provided in the following forms:

Advanced Green - a protected left turn, for traffic entering the intersection from one approach only, is provided and is followed by permissive left turns during an interval in which other traffic in the same direction and in the opposing direction is permitted to enter the intersection.

Leading Simultaneous Left Turn - a protected left turn, for traffic from opposing directions entering the intersection simultaneously, is

provided and is followed by permissive left turns during an interval in which other traffic in the same direction and in the opposing direction is permitted to enter the intersection.

Permissive/Protected Left Turn

The left turn driver is first given the opportunity to turn, permissibly, when adequate gaps appear in opposing traffic and then directed to turn left in a protected manner through a signal display. This can be provided in the following forms:

Extended Green - Permissive left turns (during an interval in which other traffic in the same direction and in the opposing direction is permitted to enter the intersection) are followed by protected left turns, entering the intersection from one approach only.

Lagging Simultaneous Left Turns - Permissive left turns (during an interval in which other traffic in the same direction and in the opposing direction is permitted to enter the intersection) are followed by protected simultaneous left turns, entering the intersection from opposing approaches.

Exclusive/Protected Left Turns

Left turns, entering the intersection from one or opposing approaches simultaneously, are directed to proceed only through the display of a green arrow. This type of phasing can take the form of an exclusive/protected left-turn phase either preceding or following the through movement phase. In this report these are referred to as

Leading Exclusive/Protected Left-Turn - A protected left-turn, for traffic from opposing directions entering the intersection simultaneously, is provided and is followed by an interval in which other traffic, excluding left-turns, in the same direction and in the opposing direction is permitted to enter the intersection.

Lagging Exclusive/Protected Left-Turn - A protected left-turn, for traffic from opposing directions entering the intersection simultaneously, is provided and is preceded by an interval in which other traffic, excluding left-turns, in the same direction and in the opposing direction is permitted to enter the intersection.

As well, this type of phasing can take the form of an

Advanced Exclusive/Protected Left-Turn - A protected left-turn, for traffic entering the intersection from one approach only, is provided and is followed by an interval in which other traffic, excluding left-turns, in the same direction and in the opposing direction is permitted to enter the intersection.

Extended Exclusive/Protected Left-Turn - A protected left-turn, for traffic entering the intersection from one approach only, is provided

and is preceded by an interval in which other traffic, excluding left-turns, in the same direction and in the opposing direction is permitted to enter the intersection.

Separate Protected Left Turn

All traffic, including the left turns, is directed to enter the intersection from one approach at a time while the traffic on all other approaches is stopped.

At the outset of the project, a study group was formed. It is intended that this study group will be deeply involved in the second phase of the project. Most members have participated by providing research information and responses to the questionnaires. In addition four members of the group provided comments on the draft questionnaire prior to it being finalized for circulation.

The members of the study group are as follows:

MUNICIPAL MEMBERS

Mr. Fred Bradbrook	City of Halifax
Mr. Fran Dunajski	City of Regina
Mr. George Dyck	City of Winnipeg
Mr. Bruce Elliott	City of London
Mr. Jan Gustafson	City of Saskatoon
Mr. Don Henderson	City of Vancouver
Mr. Dave Kaufman	Municipality of Metropolitan Toronto
Mr. Geoff King	City of Edmonton
Mr. Andre Lemire	City of Montreal
Mr. Wilf Olscher	Regional Municipality of Ottawa-Carleton
Mr. Percy Rideout	City of St. John's
Mr. Hart Solomon	City of Hamilton
Mr. John Thomas	City of Mississauga
Mr. C. Timms	City of Victoria
Mr. Rick Walshaw	City of Calgary

PROVINCIAL MEMBERS

Mr. Ross Adamson	Manitoba Department of Highways
Mr. A.H. (Jake) Bartlett	Prince Edward Island Department of Transportation and Public Works
Mr. Al Cherwenuk	Alberta Transportation
Mr. H.F. Coupe	British Columbia Transportation & Highways
Mr. Gerry Goguen	New Brunswick Department of Transportation
Mr. Milt Harmelink	Ontario Ministry of Transportation and Communications
Mr. Fred Lee	Nova Scotia Department of Transportation
Mr. A. Popoff	Saskatchewan Highways & Transportation
Mr. Francois Poulin	Quebec Ministry of Transportation
Mr. Rudy Wasmeier	Newfoundland Department of Transportation

FEDERAL MEMBERS

Mr. Terry Burtch
Mr. Hani Mokhtar

Transport Canada
Energy Mines and Resources

Also at the outset of the project contact was made with a number of individuals who have had some involvement with the the subject of left-turn phasing, timing and displays, vehicle clearance intervals and flashing operation of traffic signals.

The persons contacted were:

1. The participants in a Transportation Research Board Conference Session entitled "Left-Turn Signal Phasing: Operational Aspects and Driver Understanding"

David L. Helman, West Virginia Department of Highways and Transportation - Chairman

Bruce E. Friedman, Kimley-Horn and Associates, Inc. - Left-Turn Phasing in Florida

Slade F. Hulbert, MB Associates - Human Factors Aspects in Left-Turn Signalization

Craig F. Leiser, Minnesota Mining and Manufacturing Company - Viewpoint of National Committee on Uniform Traffic Control Devices

Raj. S. Ghaman, D.C. Department of Transportation - Use of Red Arrows: District of Columbia Experience

Ronald M. Cameron, City of Everett - Experimental Signal Display for Left-Turn Phasing

David. B. Richardson, Metropolitan Toronto Department of Roads and Traffic - Left-Turn Signal Phasing in Canada

W. Scott Wainwright, Montgomery County Department of Transportation who served as the discussant.

2. Federal Highway Administration

Mr. John Eicher
Director of Traffic Operations

R. Clarke Bennett, Chief
Traffic Control Systems Division
Office of Traffic Operations

H. Milton Heywood, Chief
Signals, Communications and Lighting Branch
Office of Traffic Operations

3. National Research Council Transportation Research Board
Robert E. Spicher
Projects Engineer, NCHRP
4. Institute of Transportation Engineers
David A. Kuemmel
Chairman
Signals Technical Committee
5. American Association of State Highway and Transportation Officials
Mr. Francis B. Francois
Executive Director

While some of the above individuals provided useful reference material, the most interesting finding from the contacts which were made related to NCHRP Project 3-29 entitled "Traffic Display Complexity". The research agency is Systems Technology Inc. with R. Wade Allen and Steven R. Shapiro as the principal investigators.

The objectives of this research are to:

- (1) determine drivers' abilities to deal with complex signal displays and identify the associated response factors;
- (2) assess the effectiveness of various complex signal display treatments currently in use; and
- (3) identify potential, future changes.

For the purposes of this research, complex signal displays are defined as those where misinterpretation by the driver may result from simultaneously viewing two or more signal and sign messages. Research will include intersection signal displays and combinations specified in Section IV-B of the U.S. Manual on Uniform Traffic Control Devices (MUTCD). Guidelines will be developed by providing effective and uniform traffic signal displays for complex situations, and recommended changes to the MUTCD will be identified.

The findings of previous work relevant to the effectiveness of complex signal displays will be reviewed to identify applicable information for use in the research (e.g., traffic signal visibility will only be considered to the extent that other research can be used to relate visibility to comprehension). A limited number of state, country and city traffic engineers will be contacted to determine:

- (1) the intersection types and geometric designs that cause the most significant problems;
- (2) the signal configurations (MUTCD and/or other) currently used; and

- (3) specific display complexity problems. Tentatively, left-turn movements and skewed and off-set intersections are considered to warrant primary emphasis.

Laboratory studies will be conducted to determine the ability of drivers to deal with complex signal displays and to assess the effectiveness of various complex signal displays currently in use. These studies will determine the specific driver related factors, such as ambiguity, information overload, etc., that cause delayed and/or faulty responses. A field study will then be conducted to validate the most promising alternatives. The operational and safety aspects of each alternative will be evaluated in addition to verifying driver behaviour and understanding.

This research was apparently initiated as a result of a number of requests which have been received to change the provisions in the U.S. MUTCD relating to the complexity of traffic signal displays and concern has been expressed by the International Association of Chiefs of Police over these matters. Although the MUTCD provides guidance on traffic control signal design configurations, it does not resolve issues related to complexity.

Previous research has considered related engineering aspects of this problem (e.g., NCHRP Project 3-23 "Guidelines for Uniformity in Traffic Control Signal Design Configurations"); however, the human factor issues associated with complex traffic signal displays and the definition of signal complexity limits have not been adequately addressed. There was a feeling that an objective assessment is needed of both the engineering and human factors aspects to determine the extent to which drivers are able to handle the multiplicity of traffic control messages, to evaluate the effectiveness of alternative treatments that are currently in use and to determine if more effective requirements and standards can be developed to give drivers information that can be understood quickly and accurately.

This research project commenced early in 1983 and it is anticipated that it will be completed in a 24-month period.

2.0 LITERATURE REVIEW

All study group members and all persons contacted in the U.S.A. were asked to identify relevant literature and, if convenient, provide copies of any papers/reports/articles that contain information in any of the following subject areas:

- . left-turn phase timing and phasing
- . left-turn signal displays
- . vehicle clearance interval timing and "all-red" phases
- . flashing (amber-red) operation of traffic signals during low traffic volume periods

The response was very encouraging. The lists of references in each of these subject areas are provided in Appendix A.

It has not been possible to obtain copies of all of the literature. The relevant items which have been obtained have been reviewed and summaries have been prepared. Documents such as Fundamentals of Traffic Engineering, the Canadian Manual on Uniform Traffic Control Devices, the U.S. Manual on Uniform Traffic Control Devices, Traffic Engineering and the Transportation and Traffic Engineering Handbook have not been summarized. Most of these are well known to practicing traffic engineers and summaries of the contents in the context of this report are not justified. The summaries which have been prepared are presented in the following sections of this chapter. The order in which the summaries appear does not reflect the degree of importance or relevance of the article but is consistent with the listing of the references which is alphabetical, based on the names of the authors.

2.1 Summary of Selected References Left-Turn Phasing and Displays

2.1.1 Agent, Kenneth R., An Evaluation of Permissive Left-Turn Phasing, ITE Journal, December, 1981.

This article describes the results of changing the operation for intersections in the State of Kentucky wherein exclusive left-turn phasing was replaced with permissive left-turn phasing. Intersection delay and accident studies were undertaken before and after the trial installations and a questionnaire was distributed to determine public opinion concerning the operations at the intersections. The summary and conclusions presented in the article are as follows:

- (1) Permissive left-turn phasing is used to some degree in nearly all states.
- (2) A standard method of traffic control to be used with permissive phasing has not been developed.

- (3) The use of permissive phasing at several locations in Lexington resulted in a 50 percent reduction in left-turn delay compared with exclusive phasing. Total intersection delay was also reduced (24 percent).
- (4) A significant percentage of the left turns made after installation of the permissive phasing was made during the green ball phase (37 percent).
- (5) During heavy opposing volume conditions, permissive phasing operates basically the same way as exclusive phasing. For opposing volumes over 1,000 vehicles per hour on a four-lane street, very few left turns were made on the green ball.
- (6) Permissive left-turn phasing did result in an increase in accidents because left-turn accidents increased. Other accident types, such as rear-end accidents, decreased as drivers became more familiar with the signals. The number of night-time accidents indicates a need for effective reflectorized signing.
- (7) The accident data indicate that care should be taken before installation of permissive left-turn phasing at locations where the speed limit is over 45 mph.
- (8) Questionnaire responses showed that over 90 percent of the drivers in the area surrounding some of the trial installations were in favor of permissive left-turn phasing.
- (9) Virtually 100 percent of the questionnaire respondents indicated they understood the meaning of the signal indications used in permissive phasing, although some did not understand the first time through the intersection.
- (10) Signing to advise motorists of the meaning of the permissive phasing is required.
- (11) An economic analysis using the average annual accident cost for a three-year "after" period showed that all of the locations had benefit-cost ratios higher than one.
- (12) The savings in time favor the use of permissive left-turn phasing; however, the increased accident potential limits its use to intersections where an accident problem would not be created. Specifically, this type of phasing should be considered at all new left-turn phasing locations. Also, some locations where exclusive left-turn phasing was once considered, but not installed because of increased delays anticipated, would now qualify for permissive-turn phasing inasmuch as the delays would not equal those associated with exclusive phasing.
- (13) Observations indicate that the arrangement of signal heads in which a separate signal head for the left-turn lane is not used is less confusing to left-turning traffic and, therefore, may lessen the accident problem.

- (14) Advance publicity should precede installations, particularly if the installation is the first of its type in an area. Confusion should decrease markedly with increased use of this type of left-turn phasing.

2.1.2 Agent, Kenneth R., and Deen, R.C., Warrants for Left-Turn Signal Phasing, Transportation Research Record 737, Transportation Research Board, 1979, pp. 1-9.

A review of the literature was conducted, along with a survey of state policies. Field data on delays and conflicts were collected before and after the installation of exclusive left-turn signalization. Left-turn delay studies were conducted at intersections that had varying volume conditions. Analysis of the effect on accidents of adding a left-turn phase was made. The relationship between left-turn accidents and conflicts was investigated. Other types of analyses concerning gap acceptance, capacity and benefit-cost ratios were also performed. It was found that exclusive left-turn phasing significantly reduced left-turn accidents and conflicts. This reduction was offset in part by an increase in rear-end accidents. Left-turn delay was reduced only during periods of heavy traffic flow. Total delay for an intersection increased after installation of left-turn phasing. Warrants were developed dealing with accident experience, delay, volumes, and traffic conflicts.

The paper describes the results of a survey of state highway agency warrants for left-turn phasing which yielded the following:

- (1) Product of the left-turn highest-hour volume and the opposing traffic is 50 000 or more.
- (2) Five or more left-turn accidents within a 12-month period (two states).
- (3) Cross product of left turns and conflicting through peak-hour volumes greater than 100 000 (two states, one listing this for traffic-actuated signals only).
- (4) Delay to left-turning vehicle in excess of two cycles.
- (5) One left-turning vehicle delayed one cycle or more in 1 hour.
- (6) At a pretimed signal, left-turn volume of more than two vehicles per approach per cycle during a peak hour.
- (7) Average speed of through traffic exceeds 72 km/h (45 mph) and the left-turn volume is 50 or more on an approach during a peak hour.
- (8) Left-turning volume exceeds 100 vehicles during the peak hour.
- (9) More than 90 vehicles/hour making a left turn.
- (10) For four-lane highways with left-turn refuges, a relationship between left-turn volume, opposing traffic volume, and posted speed.

The recommended warrants proposed to be used as guidelines when considering the addition of separate left-turn phasing (when there is a separate left-turn lane) are as follows:

- (1) Accident experience - Install left-turn phasing if the critical number of left-turn accidents has occurred. For one approach, 4 left-turn accidents in one year or 6 in two years are critical. For both approaches, 6 left-turn accidents in one year or 10 in two years are critical.
- (2) Delay - Install left-turn phasing if a left-turn delay of 2.0 vehicle-h or more occurs in a peak hour on a critical approach. Also, there must be a minimum left-turn volume of 50 during the peak hour, and the average delay per left-turning vehicle must be at least 35 s.
- (3) Volumes - Consider left-turn phasing when the product of left-turning and opposing volumes during peak hours exceeds 100 000 on a four-lane street or 50 000 on a two-lane street. Also, the left-turn volume must be at least 50 during the peak-hour period. Volumes meeting these levels indicate that further study of the intersection is required.
- (4) Traffic conflicts - Consider left-turn phasing when a consistent average of 14 or more total left-turn conflicts or 10 or more basic left-turn conflicts occur in a peak hour.

2.1.3 Andersen, D.A., Fambro, D.B., and Messer, C.J., Estimation of Unprotected Left-Turn Capacity at Signalized Intersections, Transportation Research Record 644, pp. 113-119.

The authors conclude that the left-turn capacity of an intersection approach that has no exclusive turn phase should not be expected to exceed the values provided in the tables below unless field studies at the intersection so indicate. The left-turn capacities given are based on the model developed and on the characteristics of Texas drivers.

Estimated left-turn capacity of an unprotected left-turn lane of adequate length

Proportion of Green to Cycle*	No. of Opposing Through Lanes	Combined Opposing Through and Right-Turn Volumes				
		200 Automobiles/h	400 Automobiles/h	600 Automobiles/h	800 Automobiles/h	1000 Automobiles/h
0.3	1	232	82	82	82	82
	2	280	159	82	82	82
	3	281	168	105	82	82
0.4	1	388	204	82	82	82
	2	392	276	187	114	82
	3	393	285	207	147	100
0.5	1	503	333	181	82	82
	2	524	394	292	208	138
	3	525	401	309	236	177
0.6	1	639	463	307	184	82
	2	655	512	397	302	223
	3	656	518	410	324	254
0.7	1	775	593	434	291	153
	2	787	630	502	396	307
	3	788	634	512	413	331

*Cycle length is 70 s.

**Estimated left-turn capacity of a lane with
no protected signal phase or left-turn lane**

Proportion of Green to Cycle ^a	No. of Opposing Through Lanes	Total Opposing Volumes ^b				
		200 Automobiles/h	400 Automobiles/h	600 Automobiles/h	800 Automobiles/h	1000 Automobiles/h
0.3	1	132	50	50	50	50
	2	148	95	53	50	50
	3	149	101	66	50	50
0.4	1	209	122	50	50	50
	2	223	166	119	50	50
	3	223	171	131	97	50
0.5	1	286	200	114	50	50
	2	298	237	185	122	50
	3	298	241	195	156	122
0.6	1	363	278	194	108	50
	2	373	307	251	187	122
	3	373	311	259	214	175
0.7	1	441	358	274	192	105
	2	447	378	317	252	188
	3	448	381	323	273	228

^aCycle length is 70 s.

^bIncludes right turns and throughs for one opposing lane and includes right and left turns and throughs for two and three opposing lanes.

If a left-turn lane is not provided and the left-turn volume exceeds 80 percent of the given practical capacity in the immediately foregoing table, a channelized or otherwise designated left-turn lane may be considered. If the left-turn demand is heavy when opposing approach volumes are also heavy, a separate protected left-turn signal may also be required to reduce the delays suffered by the left-turning drivers.

2.1.4 Behnam, Jahanbakhsh, Gap Acceptance as a Criterion for Left-Turn Phasing, Traffic Engineering, June, 1972: pp. 40-42.

This article discusses a study, the purpose of which was to investigate the characteristics of gap acceptance by left-turning motorists and to determine the feasibility of installing exclusive left-turn phases at signalized intersections. The author used a statistical model based on the Poisson distribution.

A simple statistical distribution was used to show that gap acceptance can be utilized as a decision-making tool related to the installation of a left-turn phase. The conclusions are summarized below:

- The capacity of left turns are reduced sharply when the opposing traffic volume exceeds 1,000 vehicles per hour.
- The delays and proportion of vehicles delayed increase significantly when opposing traffic exceeds 1,000 vehicles per hour.
- In order to apply the method described in the article successfully, the average critical gap for several intersections of similar characteristics in a city or metropolitan area must be established.

2.1.5 Benioff, Barry, and Rorabaugh, Thayer K., A Study of Clearance Intervals, Flashing Operation, and Left-Turn Phasing at Traffic Signals; Volume 4 - Left-Turn Phasing. U.S. DOT, Report No. FHWA-RD-78-46, May, 1980.

As is evident from the title of the report the study dealt with three distinct elements of traffic signal operation - clearance intervals, flashing operation and left-turn phasing. Each of these elements is dealt with in a separate report and all three are dealt with in a summary report. Accordingly the summary presented herein relates specifically to Volume IV which deals with the subject of left-turn phasing. The Foreword to Volume IV states clearly that the "report describes a limited evaluation of the safety and operational effects of a type of left-turn phasing that allows motorists to turn left during the green arrow (protected) interval and during the green ball (unprotected) interval after yielding". The study procedures included a literature review, a review of state laws, questionnaires to public officials and to drivers and field studies.

A survey of traffic engineering officials indicated that 75% of the responding agencies use a leading simultaneous left-turn phasing while only 35% use a lagging simultaneous left-turn phasing. An "advanced green" type of phasing was used by 64% of the jurisdictions from which a response was obtained. Slightly over half of the responses indicated the use of a "separate protected" left-turn phase.

The results of the driver survey were disappointing but suggested the need for a continuing public education program as an integral part of the implementation of left-turn signalization techniques.

The report in its summary and conclusions states that "implicit in the recommendations for the utilization of the protected/permmissive left-turn phasing technique is the assumption that the need for a protected left-turn interval has been established". The project was concerned with the technique of providing a left-turn phase rather than the need. Based on this, the report recommends that the protected/permmissive left-turn phasing scheme be seriously considered with the proviso that the officials responsible for the signals are convinced that the level of driver understanding of the proposed signal indication is high enough to justify the installation.

The report goes on to make the "strongest possible recommendation . . . for an integrated public education campaign wherever the protected/permmissive phasing is to be utilized".

The decision to utilize "leading" (advanced) versus "lagging" at a cross-type intersection will be influenced by the need for signal system coordination and the desired efficiency at isolated locations. The utilization of the "lagging" technique at a cross-intersection must be made for both left-turn directions from a given street in order to prevent the "trap" situation from occurring - i.e., if there is demand for the protected arrow in only one direction, the other direction must be served in order to prevent the "trapping" of vehicles in that direction wishing to turn left but effectively being prevented from doing so. Since the leading (advanced) mode can be operated independently on a directional basis, the leading

(advanced) technique will normally be found to be the most efficient at the isolated intersection situation.

The report recommends the utilization of the yellow arrow to indicate the change from the green arrow to the green ball for the leading (advanced) mode.

The report cautions that the protected/permissive left-turn phasing technique is not intended to be a safety measure but rather an efficiency alternative.

2.1.6 Etelamaki, P.E., When is Left-Turn Phasing Justified?, ITE Journal, February, 1982, pp. 18-21.

This paper described the application of the NETSIM model to estimate delay and stops with and without a left-turn phase and translates the difference in delay and stops in the two scenarios to an estimate of the excess fuel consumption as a consequence of providing a left-turn phase and hence the excess cost. An estimate of the accident reduction potential from the left-turn phase is translated into dollar benefits. These benefits are related to the costs as represented by excess fuel consumption to establish a benefit/cost ratio. The paper provides a replica of two typical analysis sheets.

2.1.7 Florida Section, ITE, Left-Turn Phase Design in Florida, December, 1981 and reported in ITE Journal, September, 1982, pp. 28-35.

This report prepared by the sub-committee of the Technical Activities Committee of the Florida Section of ITE summarizes the results of a literature review, describes field studies undertaken in Florida and summarizes a state-wide survey of left-turn phase design practices in Florida as well as a review of official Florida D.O.T. policy. The report provides recommendations which included guidelines to be used in selecting the type of left-turn phasing and the left-turn signal displays to be used with the various types of left-turn phasing.

The sub-committee conducted a search for previous reports and articles concerning the selection of left-turn phasing. Three reports describing the results of previous research projects in other states (Kentucky, Maryland, and California) were found. Each of these research projects included the collection of field data to compare the operational characteristics of protected only and protected/permissive left-turn phasing.

The research project in Kentucky (An Evaluation of Permissive Left-Turn Phasing) was conducted by the Kentucky DOT. The type of left-turn phasing at four Lexington, Kentucky, intersections was changed from protected only to either protected/permissive or permissive/protected and comparisons were made of before-and-after delay and accidents. The project also included a survey of the residents living near the four intersections.

Use of protected/permissive or permissive/protected left-turn phasing at the four intersections resulted in an average reduction of left-turn delay of 50 percent (61 percent during off-peak periods and 38 percent during peak hours) and an average reduction of overall intersection delay of 24 percent. The reduction in delay was apparently noticeable to the residents of the area as over 90 percent of

the survey responses favoured protected/permmissive or permmissive/protected left-turn phasing.

The number of left-turn angle collisions did increase following the introduction of protected/permmissive or permmissive/protected left-turn phasing. During the first six months following the phasing changes, a total of 24 left-turn angle accidents occurred at the four intersections. During the next two six-month periods, the total number of left-turn angle accidents decreased to 11 during each period, indicating that drivers were becoming more accustomed to the protected/permmissive or permmissive/protected left-turn phasing.

The Kentucky report included the following statements:

- . The reductions in delay are encouraging toward additional, but discriminating, use of protected/permmissive or permmissive/protected left-turn phasing; and, indeed, the increased accident potential limits its use to intersections where an accident problem will not be created.
- . Care should be taken before installation of protected/permmissive or permmissive/protected left-turn phasing at locations where the speed limit is over 45 mph.
- . Some survey respondents mentioned that more protected/permmissive or permmissive/protected left-turn phases should be used (specific locations were given in a few cases).
- . Signing to advise drivers of the meaning of the protected/permmissive or permmissive/protected left-turn phasing is required. The signs used at the four intersections had the legend "LEFT TURN MUST YIELD ON GREEN BALL." (However, a picture of a green ball was used instead of the words, GREEN BALL.)

The research project in Maryland (An Evaluation of Exclusive and Exclusive-Permissive Left-Turn Signal Phasing) was conducted by a private consulting firm working for the Maryland DOT. The research involved comparing the operational characteristics of 46 Maryland intersections that have either protected only or protected/permmissive left-turn phasing. At 12 of the intersections, the left-turn phasing had been changed from protected only to protected/permmissive at some time prior to the study such that before-and-after comparisons could be made.

The results of the Maryland intersection delay studies showed that protected/permmissive left-turn phasing produced a 35 percent reduction in average left-turn delay when compared to protected only left-turn phasing. The Maryland accident studies showed that at intersections with good geometrics, the accident experience for the two types of left-turn phasing did not differ significantly. Protected/permmissive left-turn phases had an average of 2.7 left-turn angle accidents and 2.7 rear-end-in-left-lane accidents per year; protected only left-turn phases had an average of 2.0 left-turn angle accidents and 1.3 rear-end-in-left-lane accidents per year.

The Maryland report included the following statements:

- . Use of protected/permmissive left-turn phasing can be expected to result in an average decrease in left-turn delays of 30 percent. Additional time savings should be experienced by other drivers as a result of a redistribution of the green time previously dedicated to protected only left-turn phases.
- . Six left-turn angle accidents or six rear-end-in-left-lane accidents per year were found to be the critical number of accidents above which a protected/permmissive left-turn phase should be considered abnormal. The critical number of the combined left-turn angle and rear-end-in-left-lane accidents is ten.
- . Accident rates will tend to increase initially and then drop off and stabilize with left-turn phases changed from protected only to protected/permmissive operation. The acclimation period could be from four to six months.

The Maryland report indicated that protected/permmissive left-turn phasing might result in operational difficulties under the following conditions:

- . The median between the left edge of opposing left-turn lanes exceeds 20 feet.
- . A median is present and more than 20 percent of the opposing left turns are large trucks.
- . Sight distance to opposing traffic is not sufficient to judge for adequate gaps.
- . The safe stopping sight distance for the opposing through traffic meets or exceeds the distance they would travel during an acceptable gap. When this condition occurs, the downstream approaching traffic may not have adequate stopping distance to avoid an accident if a vehicle turning left is for some reason delayed in the intersection.
- . The speed of opposing traffic is high or is subject to considerable fluctuations.
- . Double left-turn lanes are operating.

The research project in California (A Study of Clearance Intervals, Flashing Operation, and Left-Turn Phasing at Traffic Signals, Volume 1 - Summary Report and Volume 4 - Left-Turn Phasing) was conducted by two private consulting firms working for the Federal Highway Administration. The research involved comparing the operational characteristics of three intersections in the Los Angeles, California, area that were changed from protected only to protected/permmissive left-turn phasing. The project also included a national survey of left-turn phase design practices and a driver survey.

The results of the California delay studies showed that overall intersection delay was reduced by 25, 38 and 46 percent at the three intersections through the introduction of protected/permissive left-turn phasing. However, total left-turn angle accidents at the three intersections increased from one to 21 following the left-turn phasing change. Because the "after" accident data were compiled for a one year period immediately following the phasing change, it is possible that many of the "after" accidents occurred during the six-month adjustment period immediately following the change.

Traffic engineers from 142 cities, 49 counties, and 41 states responded to the national survey on left-turn design practices. The following conclusions were derived from the survey responses:

- . A majority of the agencies use both protected/permissive and protected only left-turn phasing.
- . A majority of the agencies do not use permissive/protected left-turn phasing at any intersections.
- . In locations where the use of protected/permissive left-turn phasing has been implemented, studies to determine the effect have not generally been conducted.

The California project included a survey of 354 drivers in California, Illinois and Connecticut. Approximately 87 percent of the drivers knew the proper meaning of the green arrow and yellow arrow indications. However, only 81 percent knew that the circular green indication meant that left-turn drivers could make a left turn, but must yield to opposing traffic; 7 percent thought that opposing traffic must yield to them and the remaining 12 percent indicated that it was illegal to turn left on the circular green. Older drivers had a greater tendency to give incorrect answers.

The California report included the following statements:

- . The use of protected/permissive left-turn phasing will reduce delay to all vehicles entering the intersection compared to protected only left-turn phasing.
- . The use of protected/permissive left-turn phasing will increase left-turn angle accidents compared to protected only left-turn phasing.
- . The present level of public understanding of the meaning of the circular green indication when used following the green arrow is unacceptably low considering the accident potential of left turns made across opposing traffic.
- . Enthusiasm with the delay reduction results must be taken in context with the realization of the need for increased public education as well as the accident potential involved. From the standpoint of delay reduction, protected/permissive left-turn phasing is worthy of increased consideration as part of the continuing effort to increase the efficiency of traffic signal operations.

The following recommendations were advanced with respect to the guidelines to be used to select the type of left-turn phasing:

- Protected/permissive left-turn phasing should be provided for all intersection approaches that require a left-turn phase unless there is a compelling reason for using another type of left-turn phasing. Protected/Permissive left-turn phasing is the most common type of left-turn phasing currently in use in the State of Florida. Drivers favor this type of left-turn phasing because the reduction in intersection delay is very noticeable. If the decision between providing protected/permissive or protected only left-turn phasing is not obvious, the traffic engineer should initially operate the left-turn phase as protected/permissive on a trial basis. If satisfactory operation results, the protected/permissive left-turn phasing should be retained. If unsatisfactory operation results, the protected/permissive left-turn phase should be converted to another type of left-turn phasing.
- Protected only left-turn phasing should be provided for an intersection approach if any of the following conditions exist:
 - (1) Double left-turn only lanes are operating.
 - (2) Intersection geometrics force the traffic engineer to provide the left-turn driver with an exclusive signal head that cannot be shared with adjacent through drivers.
 - (3) Sight distance to opposing traffic is less than 250 feet when the opposing traffic is traveling at 35 mph or less, or less than 400 feet when the opposing traffic is traveling at 40 mph or more. This represents approximately five seconds of travel time which was the first gap size universally accepted by all left-turn drivers in the California research project.
 - (4) The approach is the lead portion of a lead/lag intersection phasing sequence.
- Protected only left-turn phasing might be appropriate for an intersection approach if any of the following conditions exist and the traffic engineer, using his best professional judgment, has the opinion that allowing permissive left turns will be unduly hazardous:
 - (1) Poor sight distance to opposing traffic because of roadway curvature (horizontal or vertical) or opposing left-turn vehicles.
 - (2) Speed limit of opposing traffic is higher than 45 mph.
 - (3) Left-turn traffic must cross three or more lanes of opposing through traffic.
 - (4) Protected/permissive left-turn phasing is currently in use and the number of left-turn angle accidents caused by left-turn drivers on this approach exceeds six per year.

- (5) Unusual intersection geometrics exist that will make permissive left turning particularly confusing or hazardous.
- Permissive/protected left-turn phasing can be used effectively for some intersection approaches if the traffic engineer feels that the advantage to be gained is worth the possible violation of driver expectation. However, use of this type of left-turn phasing should be limited and should be restricted to only the following situations:
 - (1) T intersections, where opposing U-turns are prohibited.
 - (2) 4-way intersections where the opposing approach has prohibited left turns or protected left-turn phasing.
 - (3) 4-way intersections where the left-turn volumes from opposing approaches do not substantially differ throughout the various time periods of a normal day. This is because of a limitation that makes it impossible to overlap the through movements with the left-turn phases.
- Split phasing can be used effectively if any of the following conditions apply:
 - (1) Opposing approaches are offset to an extent that simultaneous left turns from opposing directions would be impossible or hazardous.
 - (2) Left-turn volumes are extremely heavy on opposing approaches and both are nearly equal to the adjacent through movement critical lane volume.
 - (3) Left-turn volume is extremely heavy on an approach that does not include a separate left-turn lane.
 - (4) Drivers are permitted to turn left from more than one lane, but drivers are permitted to also use the right-most left-turn lane as a through lane.

The following recommendations were advanced concerning the left-turn signal displays to be used with the various types of left-turn phasing:

- Protected/permissive left-turn phasing - a 5-section cluster (type s in the MUTCD) centered over the lane line between the left-turn lane and the left-most through lane should be used. The 5-section cluster could serve as one of the two required through traffic signal heads. No supplemental signing should be provided.
- Protected only left-turn phasing with a single left-turn lane - a 3-section vertical signal head (from top to bottom - circular red, circular yellow, left-turn green arrow) should be centered over the left-turn lane and a supplemental sign having the legend "LEFT-TURN SIGNAL" or "LEFT TURN ONLY" should be provided. If it is absolutely essential that permissive left turns not be allowed during circular red burn-out, a 4-

section cluster (type e in the MUTCD) should be used instead of a 3-section vertical head.

- Protected only left-turn phasing with double left-turn lanes - a single 3-section vertical signal head (from top to bottom - circular red, circular yellow, left-turn green arrow) should be centered over the lane line between the left-turn lanes; or two 3-section vertical signal heads should be used, with one centered over each left-turn lane. A supplemental sign having the legend "LEFT-TURN SIGNAL" or "LEFT TURN ONLY" should be located next to each protected only left-turn signal head.
- Permissive/protected left-turn phasing - if the protected left-turn phase always clears at the same time as the adjacent through phase, a 4-section vertical signal head (from top to bottom - circular red, circular yellow, circular green, left-turn green arrow) should be used; if the protected left-turn phase sometimes clears at a different time than the adjacent through phase, a 5-section cluster (type s in the MUTCD) should be used. In either case, the signal head should be centered over the lane line between the left-turn lane and the left-most through lane. The signal head could serve as one of the two required through traffic signal heads. No supplemental signing should be provided.
- Split phasing - a left-turn green arrow should be displayed in the left-most signal head.

2.1.8 Gurnett, George, Intersection Delay and Left-Turn Phasing, Traffic Engineering, June, 1969: pp. 50-53.

This article presents the results of "before" and "after" delay studies undertaken at three intersections in Los Angeles County. The studies included observations on the stopping of vehicles and stopped time delay. The following points were presented in the summary of the article:

- (1) Intersection delay is substantially increased by the installation of minor movement left-turn phasing. Delay per vehicle increased from 22% to 121% after left-turn phasing was installed. When left-turn phasing is installed on all approaches, peak hour delay increases of over 100% may be expected. Delays of from 8-12 seconds per vehicle may also be expected.
- (2) Left-turn delay increased 26% or 10 seconds per vehicle at the location that had left-turn phasing installed on all approaches. In contrast, at the location where left-turn phasing was installed for only one street, left-turn delay decreased slightly.
- (3) Left-turn phasing does not seem to be justified from an accident-cost reduction standpoint for most high volume major intersections. Accident reductions of 75% for left-turn collisions and 50% for right angle collisions after left-turn phasing must be balanced by an increased delay cost of about 10 seconds per vehicle. Normally these accident reductions are only about one-third to one-fourth of the delay

costs. Nevertheless, accident savings for each intersection should be considered separately.

2.1.9 King, L. Ellis and Plummer, Ralph W., Meaning and Application of Colour and Arrow Indications for Traffic Signals. Research Project 31, West Virginia University.

Various methods and configurations of left-turn signal indications were evaluated in this project which was designed to develop a standard for such indications. From a literature review and responses to a questionnaire, a controlled laboratory study was designed which utilized both colour movies and colour slides and investigated nineteen combinations of signal indications for their effectiveness in conveying their intended message to the driver.

The signal sequences tested (in the field study) are as illustrated below.

The results which were obtained are summarized as follows:

1. Signal indication sequences 12 and 13 proved to be superior in conveying the messages (1) that the driver had a protected left turn, (2) that the protected left turn was about to terminate and (3) that the driver did not have a protected left turn during part of the signal cycle.

SEQUENCE 2*
Phases

R	1----
A	-----4
G	-2,3-
←	-2----

SEQUENCE 12
Phases (same as sequence 13)

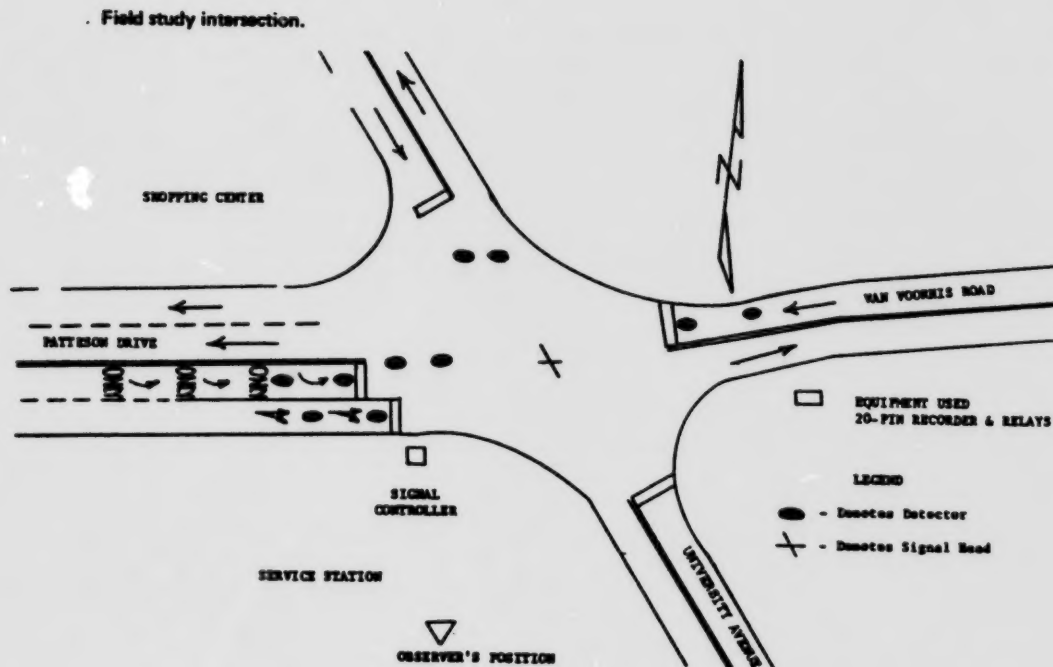
R	
A	
G	
←	←
AA	GA

SEQUENCE 7
Phases

R	1-----
A	---3--5
G	-2,3,4-
←	-2-----

SEQUENCE 13
Phases

R	1-----
A	-----5
G	-2,3,4-
←	AA ---3---
←	GA -2-----



- Sequences 12 and 13 encouraged left-turning motorists to yield the right-of-way more often than sequences 2 and 7.
- The starting up times for left-turn and right or through vehicle movements were lower for signal sequences 12 and 13 than for sequences 2 and 7.
- Signal indication sequence 7 proved to be the most ineffective of the four sequences tested. There was evidence of driver hesitation on both approach lanes during the third indication phase of this signal.
- Fewer traffic flow violations resulted with sequences 12 and 13 than with sequences 2 and 7.
- Speeds of left-turning vehicles were affected by the signal indication sequence, and driver left-turning speeds were higher with signal sequences 12 and 13.

Based on ease of installation and driver expectation, the report recommends that signal sequence 13 be given preference over sequence 12.

2.1.10 Machemehl, Randy, and Lin, H.J., Guidelines for Left-Turn Lanes and Signal Phases, 1982 CTP, 134 ITE.

This paper was presented at the 1982 Annual Meeting of ITE. The paper describes research which pursues gap acceptance theory to estimate left-turn capacity and assesses the impact of cycle length, cycle split, length of left turn lane, number of crossing lanes and headway distributions.

In summary the paper states that "the performance measures which are described ... are only a small sub-set of all those which might be considered significant. The choice of specific performance measures and particularly the magnitude of those measures which are assumed to justify left-turn signal phases should likely be based upon engineering judgment and experience" and that "performance measures and magnitudes presented ... have been suggested by researchers and practicing engineers. The functional and graphic relationships (presented in the paper) permit use at any selected performance measure level".

2.1.11 McKay, B.J., Lead and Lag Left-Turn Signals, Traffic Engineering, April, 1968, pp. 50-57.

This article describes the advantages and disadvantages of the permissive/protected and protected/permissive options in the provision of separate phases for left-turn movements. (These are discussed in various other summaries presented in the report and hence need not be included in this summary.)

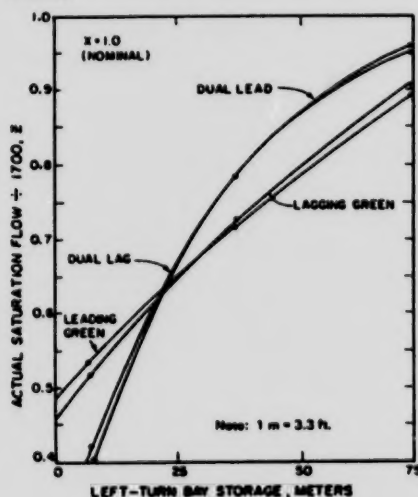
2.1.12 Messer, C.J., and Fambro, D.B., Effects of Signal Phasing and Length of Left-Turn Bay on Capacity, Transportation Research Record 644, Transportation Research Board, 1977, pp. 95-101.

The results of studies showed that traffic delay increases and signal capacity decreases for a left-turn bay when traffic interactions and flow blockages occur between left-turning and through automobiles. High left-turn volumes and short bay storage lengths experienced the most severe reductions in capacity. Delay begins to occur when the signal saturation ratio reaches 0.6-0.8 for bay storage lengths of 5-10 automobiles respectively.

The operational quality of service provided by a left-turn bay design was shown to depend to a significant degree on how well the traffic engineer signalizes the intersection. A design can fail simply because the signal saturation ratio approaches 1.0. In addition the signal phase sequence was found to affect operational performance. The leading and lagging phase sequences performed slightly better for a short bay length and the dual lead and dual lag sequences were superior for bay storage lengths over 22.9 metres (75 feet); however, all four signal phase sequences experienced considerable reductions in capacity at high saturation ratios and short bay lengths.

The phase timing of left-turn signals at pre-timed signalized intersections should account for a reduction in saturation flow that may occur during rush hour traffic conditions as illustrated in the figure on the following page.

Reduction in left-turn saturation flow by phasing.



2.1.13 Request IV-16 (Intr.), Signal Display for Perm/Prot Left-Turn Phasing, Federal Register (Vol. 46, No. 127), July 2, 1981: pp. 3-7.

The Tennessee Department of Transportation (TNDOT) requested an interpretation of a previous official ruling (sg-38) as to whether the simultaneous display of a CIRCULAR GREEN and a left-turn GREEN ARROW in the same signal head over an exclusive left-turn lane is permissible at locations where permissive/protected left-turn phasing is used. The TNDOT states that the simultaneous display of these two signal indications would make the installation of additional, expensive equipment for separate signal indications unnecessary.

Official Ruling Sg-38 did not address the permissive/protective left-turn phasing situation described in the Tennessee request. The FHWA has determined that under the MUTCD, as presently written, it is acceptable for permissive/protected left-turn phasing, regardless of the lateral position of the signal faces, to display a CIRCULAR GREEN with a left-turn GREEN ARROW in the signal face that controls left-turn traffic. The sign LEFT TURN SIGNAL shall not be used with the signal display. In the opinion of the FHWA, the preferred practice for permissive/protected left-turn operation, is to locate the signal face that controls turning traffic: (1) Over the lane line between the exclusive left-turn lane(s) and the adjacent through lane, or (2) Over the through lane that is adjacent to the exclusive left-turn lane.

For permissive/protected left-turn operation, the circular lens display on each of the several signal heads, regardless of location, which control a specific approach, shall display the same color indication during each interval. Any

specific information concerning protected turning movements shall be displayed by means of a green turn arrow incorporated into the signal face nearest the proper lane.

In the case of protected only left-turn phasing, a left-turn signal display for an exclusive turn lane shall not display permissive circular indications and the sign LEFT TURN SIGNAL shall be located adjacent to each left-turn signal face unless the face consists entirely of arrow indications (reference Section 4B-12(4) of the MUTCD).

2.1.14 Spitz, Salem, Left-Turn Phases - Who Needs Them?, Traffic Engineering, December, 1974: pp. 16-18.

This article presents the results of a Los Angeles area ITE Technical Committee study which included field observations of delay at various intersection configurations in the City of Los Angeles, Los Angeles County, the City of Downey and at suburban intersections under the jurisdiction of the California Division of Highways. The findings from the study are summarized below.

- (1) Delay to left turns (as measured by the proportion of signal cycles in which left-turn demand was observed to exceed left-turn capacity) increases as the product of left turns times opposing traffic increases.
- (2) For products below 100,000 to 125,000, the mean proportion of delay cycles is less than 16 per cent of all cycles during the hour with that product.
- (3) For all products, the 95 percent confidence interval of proportion of delay cycles is so great that use of the mean value as typical is misleading; e.g., with a measured product of 135,000, the left-turn delay problem could be serious, with delay to one out of four cycles; moderate, with delay to one out of six cycles; or minor, with delay to only one out of eight cycles.
- (4) Use of a product of left turns times opposing traffic to determine need for a left-turn phase is a poor technique below about 125,000 (which could mean delay to as few as 12 percent of the signal cycles during peak hours) and questionable even over 200,000 (which could represent only 24 percent delay during the heaviest travel hours).

The conclusions formulated by the Committee are as follows:

- (1) Although other problems are conceivable, the two most common for which left-turn phasing might be applicable are:
 - . excessive left-turn collisions;
 - . excessive left-turn delay.Factual determination of either of these problems can only be through field measurement. Projections of delay based upon volumes alone cover such a broad range when compared with the real situation that they are almost meaningless.

- (2) A cycle-by-cycle check as performed by the Los Angeles Area ITE Left-Turn Phasing Committee is a sure way of establishing the proportion of the time (cycles) that real left-turn delay occurs.
- (3) At locations where field studies cannot be made (nonexisting intersections), the projected product of left-turn and opposing flow should probably be used as an indication of locations to be studied after signalization is completed.

The Recommendations of the Committee were as follows:

- (1) Left-turn phasing should only be considered as a solution to a problem (either measured or projected) and only after less restrictive measures (for the majority of traffic involved) have been considered and rejected on the basis of factual engineering study.
- (2) The two most common problems - excessive left-turn collisions and excessive left-turn delay - should be determined by real measurement (as opposed to projection) whenever possible.
- (3) The product of left turns times opposing volume should not be used to indicate need for left-turn phasing.
- (4) Measurement of delay to left-turn vehicles should be made by the simple technique used by the committee:

Record for each signal cycle (or at some prechosen interval, such as one minute, where there is no signal):

- (a) Number of vehicles standing in the left-turn pocket at the time the signal goes green for the approach being studied.
- (b) Number of vehicles that turn left (or make a U turn) from the study approach during the green and yellow.
- (c) Subtract the number in (b) from the number in (a). (As it is almost always possible for one vehicle to turn left each cycle, (b) +1 would result in delay cycle only for vehicles which had to wait more than one cycle.)
- (d) If the result is positive, that cycle was a 'delay' cycle; if zero or negative, cycle was not a 'delay' cycle.

2.1.15 Technical Council Committee 76-1, Left-Turn Signal Warrants, ITE Technical Notes, May, 1980.

The objective of the study was to develop warrants for the installation of left-turn phasing. The following is a list of the major findings of this study:

1. There are very few agencies with specific warrants for separate left-turn phases. Most engineers use some types of guidelines; however, there was no unanimity on the guidelines used.

2. Most engineers indicated that any warrants developed for left-turn phasing should not be absolute warrants.
3. Average values obtained from field data for intersection approaches warranting addition of left-turn phasing were comparable to values in currently used warrants; however, there was a large variation in the data. The large range in data collected at locations where the engineer felt left-turn phasing was warranted illustrates the lack of uniformity in this area.
4. The questionnaire revealed that a valid left-turn signal warrant should include a combination of left turn and opposing volumes and the number of opposing lanes. The field data indicated the following approximate values:

<u>Number of Opposing Lanes</u>	<u>Product of Opposing and Left-Turn Peak Hour Volumes</u>
1	45,000
2	90,000
3	135,000

These values agree closely with the current warrants and guidelines revealed by the questionnaire.

5. The number of opposing vehicles in the peak hour or the sum of the opposing and left-turn peak volumes have been used as guidelines in the past. The field studies indicated the following approximate values:

<u>Number of Opposing Lanes</u>	<u>Opposing Peak Hour Volume</u>	<u>Sum of Opposing and Left-Turn Peak Hour Volumes</u>
1	400	500
2	800	900
3	900	1,000

The use of the opposing peak hour volume alone would not give conclusive results. Using the sum of opposing and left-turn peak hour volumes provides an alternate to using the product of the two volumes.

6. Both the questionnaire and the field data indicated that the minimum left-turn volume necessary to warrant a left-turn phase was in the range of 100-125 vehicles per hour or approximately 2 vehicles per cycle.
7. The questionnaire respondents listed seconds per vehicle as the best measure to determine left-turn delay. The average value given as the maximum delay to which a left-turn vehicle should be subjected was 96 seconds. The average left-turn delay per vehicle at the field sites was 44 seconds. However, using the delay per vehicle criterion presents a problem because it does not consider the left-turn volume.

Using vehicle hours of delay considers both delay per vehicle and volume.

8. The left-turn delay given in vehicle hours, necessary to warrant left-turn phasing was revealed by both the questionnaire and the field data to be in the range of 1.5 to 2.0.
9. Considering all sources of input, a representative accident warrant would be as follows:

Install left-turn phasing when four or more left-turn accidents occur on an intersection approach in a one-year period or six or more occur in a two-year period.

10. Most of the respondents to the questionnaire indicated they believed traffic conflicts could be used as a warrant. However, there was no agreement as to the number of conflicts necessary. (The review of literature found one study in which conflicts were used as a warrant.)
11. A slight majority of the questionnaire respondents indicated that warrants should reflect different speed limits.
12. There has been little use of computer simulation or benefit-cost analysis when considering the use of separate left-turn phasing.
13. Protective/permissive left-turn phasing has had widespread use and was generally preferred over exclusive/protected phasing.
14. Generally, a five-section signal head is used or leading left-turn phasing at protective/permissive installations while a four section signal head is used for lagging left-turn phasing.
15. No agreement exists as to whether special signing is necessary when using protective/permissive phasing. While no single sign has gained widespread acceptance, the most frequently mentioned sign read as follows:

LEFT TURN YIELD ON GREEN BALL

2.1.16 Travers Associates Consultants, Inc., An Evaluation of Exclusive and Exclusive-Permissive Left-Turn Signal Phasing, MDDOT, State Highway Administration, April, 1981.

This report provided the findings of studies of several intersections with exclusive (E) and exclusive-permissive (EP) left-turn phasing. The studies included field surveys of left-turn delays and traffic conflicts associated with left-turning vehicles. In addition, the accident histories at intersections with E and EP left-turn phasing were examined. Also, comments and experiences of local traffic officials were included in the evaluation.

- o The study found that an EP left-turn phase could reduce left-turn delays by approximately 30 percent and as much as 50 percent.

- o Left-turn delays versus left-turn volumes were found to have a linear relationship up to capacity conditions.
- o Traffic conflicts can be expected to be higher at an EP signal than at an E signal.
- o Accidents at an E signal may not increase significantly when changed to an EP signal.
- o Based on the available data, the critical number of accidents at an EP signal has been determined to be 10 per year. In other words, an EP signal with more than 10 accidents annually probably has an abnormally high accident history.
- o A set of traffic parameters are listed for use by traffic engineers as part of their decision making process in designing left-turn phasing. These characteristics cover the speeds of opposing traffic, grades, acceptable gaps, estimated delays and geometrics.

2.1.17 United States D.O.T., FHWA, Guidelines for Signalized Left Turn Treatments, November, 1981.

This report presents information on various left turn treatments and describes trade-off criteria relevant to the determination of the type of left turn treatment which should be applied (not necessarily in the form of a separate left-turn phase). The report also provides guidelines related to the selection of the type of phasing and lists the factors that should be considered when selecting the proper phasing scheme. The report also contains the following guidelines relating to the selection of phasing:

System Considerations - Signals placed in a system configuration require consideration of the effects of the left-turn phasing on the system operation.

- . Dual Left-Turn Phasing - If a time space diagram indicates that traffic on each approach to the intersection arrives at the same time, dual left-turn phasing should be implemented.
- . Lead-Lag Left-Turn Phasing - If a time space diagram indicates that traffic on each approach to the intersection arrives at an appreciable difference in time (10 seconds or more) lead-lag phasing should be implemented.

Protective/Permissive Phasing - Protective/permissive left-turn phasing enables a motorist to complete a left-turning movement during a protected and/or an unprotected interval. This treatment has proved effective in increasing the left-turn capacity of signalized intersections without having to change the signal timing. It should be pointed out that this type of phasing helps to reduce congestion problems but may not reduce an accident problem. If accidents continue to be a problem after a protective/permissive phase is implemented, consideration should be given to eliminating the permissive turn.

This type of phasing is easily implemented at intersections with either pretimed or traffic actuated controllers. For maximum efficiency, it is essential that the proper left-turn signal displays be used and the situation may also dictate use of signal instruction signs. Problems can occur whenever the phasing sequence at the intersection is such that the permissive left-turn and its adjacent through movement end before the opposing through movement does. Drivers of left-turning vehicles may anticipate a yellow ball being displayed to both approaches. In other words, they expect the opposing through movement to stop and they then turn in front of oncoming traffic not realizing that such traffic has a green signal indication. Four special condition permissive/protective concepts are presented below.

- Lagging Left With Skip Phase - The protected only left-turn phase has the potential to substantially reduce the capacity of the intersection due to movement of one lane of traffic while several other lanes are held. Increased delay and reduced capacity result. One method of obtaining maximum utilization of the available green time is to use a permissive/protected phasing with a presence loop in the turn lane. Should the left-turning vehicles be able to clear on the green ball indication the detector would clear and the protected portion of the left-turn phase would be skipped. The presence of a vehicle in the area of detection would call in the lagging left-turn as a protected maneuver.
- Leading Left With an Offside Loop - Another special problem is the blockage of the shared through/left-turn lane by a turning vehicle waiting for an opportunity to turn through the opposing traffic. Going to three phase operation reduces the intersection capacity. A loop detector placed in the path of the left-turning vehicle but out of the path of the through vehicle can be used to extend the leading protected phase but terminate it immediately upon the lack of left-turning traffic.

When applying this concept, care must be exercised to ensure that a $\phi A' - \phi A - \phi A'$ sequence cannot occur. By placing a recall on ϕB this can easily be accomplished. Thus $\phi A'$ extended as long as the offside loop is occupied, followed by ϕA and at least a ϕB minimum would result.

- Leading Left With Mixed Mode Detectors - The absence of a left-turn lane often results in a queue forming in the left lane and a reduction in the phase capacity. One approach to solving this problem is to use a presence mode loop detector in conjunction with unit mode detectors. The presence of a queue due to a waiting left-turn vehicle will hold the green indication until the traffic clears or the maximum extension is reached.
- Lagging Left Based on Left-Turn Queue Length - A more recent concept involving protected turning intervals at traffic actuated controllers using detectors placed two or three car lengths behind the stop line. A "non-lock" memory feature is used in the controller to ensure that the left-turning interval is not displayed unless a vehicle presence is sensed at the beginning of the phase. This means that the left-turn interval will not be displayed on any cycle in which a sufficient queue of left-turning vehicles

has not accumulated. This technique uses the lagging permissive turning interval. Under light traffic conditions, left-turn vehicles are handled adequately on the permissive phase provided that enough gaps exist in the oncoming traffic stream. When the left-turning capacity becomes inadequate, a queue will be generated and this will initiate the left-turn interval.

2.2 Summary of Selected References Vehicle Clearance Timing

2.2.1 Benioff, B., Dock, F.C., and Carson, C., A Study of Clearance Intervals, Flashing Operation and Left-Turn Phasing at Traffic Signals, (Volume 2) - Clearance Intervals. U.S. DOT, Report No. FHWA-RD-78-46, May, 1980.

The more relevant findings and conclusions from this study are summarized in the following.

State laws regulating driver behaviour at yellow lights can generally be categorized as one of the following:

- (1) the yellow is a warning that the red light will come on shortly at which time it will be illegal to enter the intersection (Uniform Vehicle Code) (25 states);
- (2) drivers must have completely cleared the intersection by the time the light turns red (13 states);
- (3) drivers must not enter the intersection on the yellow unless it is unsafe to do otherwise (11 states and the District of Columbia).

The first two of these laws imply formulas for the length of the yellow interval that allow prudent drivers to comply with the law. A uniform yellow is another type of policy that is used by many jurisdictions in the United States and around the world. There have been insufficient safety studies to determine which criterion is best. Excessively long yellow intervals, however, are definitely hazardous.

Over half the public agencies surveyed use the procedures of the Transportation and Traffic Engineering Handbook for setting yellow intervals; 30 percent have used a uniform yellow throughout their jurisdiction or in selected portions of it. An interesting finding was that the procedure used for setting yellow intervals was statistically independent of the state law regarding the meaning of the yellow light.

Most drivers surveyed in this project did not know the fine points of their state's law regarding behaviour at yellow intervals.

After the uniform yellow concept was field tested in Fresno, California, the accident pattern changed in several ways. At 80 selected signalized intersections

the severity of accidents was down, approach turn accidents were up, and the "other" category of accidents was down. Accidents occurring in the CBD increased.

Certain of the conflict measurements were correlated with accidents. The strongest of these correlations were (a) between total accidents and total conflicts and (b) between approach turn accidents and left-turn conflicts. Running-the-red-light violations showed some correlation with accidents but not as much as some of the other types of conflicts.

Most agencies (95 percent) use all-red intervals, but a majority of those that do have no specific warrant for their use. Larger agencies have more tendency to use all-red intervals.

The all-red studies indicated a marked reduction in accidents for a range of circumstances. Property damage only, right-angle, "other" and total accidents were the types most significantly affected. Even rear-end accidents went down in some instances. The all-red intervals did not have to be long to be effective. Interval lengths equal to and less than the calculated parameter -- intersection width divided by approach speed -- produced the most significant reductions in accidents. This parameter corresponds very closely with that recommended by the Transportation and Traffic Engineering Handbook -- intersection width plus vehicle length divided by approach speed. As a practical consideration, the Transportation and Traffic Engineering Handbook formula was substituted for the calculated parameter in the "conclusions".

The violation data showed that drivers have no significantly different tendencies to enter a signal on a red indication whether or not an all-red interval is present.

Changing a clearance interval by adding an all-red interval was shown to produce no significant changes in mean delay and mean proportion of vehicles stopping. However, individual intersections showed increases in delay and the proportion stopping. At these intersections, the fuel consumption and vehicle emissions were increased.

The report offers the following conclusions:

- (1) A uniform yellow throughout a metropolitan area -- or at least the approximation to the uniform yellow obtained in this study -- is not unequivocally effective in increasing safety. To coexist with a law that follows the Uniform Vehicle Code, a uniform yellow would have to be set at the highest yellow implied by that law or else there would be inevitable violations of that law in the area. Using such a high value for the yellow interval when it is not otherwise needed is unsafe.
- (2) A uniform yellow for portions of a metropolitan area not only seems reasonable but will be the de facto result of applying a uniform practice to uniform traffic situations.
- (3) Intersections with a right-angle accident rate greater than 0.8 right-angle accidents per million entering vehicles should be considered for addition of an all-red interval.

- (4) The limiting length of the all-red interval should be that implied by the Transportation and Traffic Engineering Handbook:

$$\frac{\text{Street Width} + \text{Vehicle Length}}{\text{Velocity}}$$

The following recommendations were not validated by this study but, based on the conventional wisdom of traffic engineers, seemed worthy of mention:

- (5) All-red intervals should not be used at all intersections, or even at a majority of intersections. They should be the exception, not the rule. The adopted yellow interval policy must consider this fact.
- (6) All-red intervals should not be used just to expedite left turns.

Needed research as suggested by the report is in the area of determining how different clearance interval practices affect drivers' decisions about stopping. Such research would probably best be conducted in a laboratory setting using test subjects and a simulated driving environment. It would then be appropriate to field test the most promising practices on a rather large scale. Conditions for the field test would have to be highly controlled, much more so than the uniform yellow policy tested in this study where area-wide uniformity was not obtained.

Although the study showed a maximum value for all-red interval lengths for optimal reduction of accidents, further research is needed to validate or refine the formula for determining all-red interval length.

2.2.2 Bissell, H.H., and Warren, D.L., The Yellow Signal is Not a Clearance Interval, ITE Journal, February 1981, pp. 14-17.

The authors encourage the traffic engineering profession to recognize the yellow change interval for what it is and to discontinue referring to it as a "clearance interval". The authors go on to point out that most past research studies have been based on the concept of the yellow serving as a clearance interval and do not, therefore, necessarily address real problems associated with the change period of the signal cycle. The article points out that the yellow signal interval has been working for years at thousands of intersections and although the accident rate associated directly with the timing of the yellow change interval is unknown, it is believed to be relatively low compared to the total accident picture.

The authors recommend that the timing of the yellow change interval should be based on the approach speed of traffic using a one-second perception and reaction time and a deceleration rate of 3 metres (10 feet) per second per second. An all-red clearance interval should be considered if the number of right-angle collisions exceeds one accident per million entering vehicles.

2.2.3 Butler, J.A., Another View on Vehicle Change Intervals, ITE Journal, March, 1983, pp. 44-48.

The author recommends the formulas on the following page to determine the yellow and all-red interval for vehicle clearance times:

$$y = t + \frac{v}{2a + 64.4g}$$

where y = yellow interval, in seconds
 t = reaction time, set at 1.0 second
 v = 85th percentile approach speed, in feet/second
 a = deceleration rate, set at 10 feet/second/second
 g = grade of approach over the breaking distance in percent/100

$$r = \frac{w + l}{v}$$

where r = all-red interval, in seconds
 w = width of intersection, in feet
 l = length of vehicle, set at 20 feet
 v = speed of vehicle, in feet/second

and provides the following tables which are generated by the foregoing formulas.

Yellow Intervals

85th Percentile Speed	Grade of Approach								
	+4%	Uphill		Level					Downhill
		+3%	+2%	+1%		-1%	-2%	-3%	-4%
25	2.63	2.68	2.73	2.78	2.84	2.90	2.96	3.03	3.11
30	2.95	3.01	3.07	3.14	3.21	3.28	3.36	3.44	3.53
35	3.28	3.35	3.42	3.49	3.57	3.66	3.75	3.85	3.95
40	3.60	3.68	3.76	3.85	3.94	4.04	4.14	4.25	4.37
45	3.93	4.02	4.11	4.20	4.31	4.42	4.54	4.66	4.80
50	4.26	4.35	4.45	4.56	4.68	4.80	4.93	5.07	5.22
55	4.58	4.69	4.80	4.92	5.04	5.18	5.32	5.47	5.64
60	4.91	5.02	5.14	5.27	5.41	5.56	5.71	5.88	6.06
65	5.23	5.36	5.49	5.63	5.78	5.94	6.11	6.29	6.48

All-Red Intervals

85th Percentile Speed	Width of Approach										
	20'	30'	40'	50'	60'	70'	80'	90'	100'	110'	120'
25	1.09	1.36	1.63	1.90	2.18	2.45	2.72	2.99	3.27	3.54	3.81
30	0.91	1.13	1.36	1.59	1.81	2.04	2.27	2.49	2.72	2.95	3.17
35	0.78	0.97	1.17	1.36	1.55	1.75	1.94	2.14	2.33	2.53	2.72
40	0.68	0.85	1.02	1.19	1.36	1.53	1.70	1.87	2.04	2.21	2.38
45	0.60	0.76	0.91	1.06	1.21	1.36	1.51	1.66	1.81	1.97	2.12
50	0.54	0.68	0.82	0.95	1.09	1.22	1.36	1.50	1.63	1.77	1.90
55	0.49	0.62	0.74	0.87	0.99	1.11	1.24	1.36	1.48	1.61	1.73
60	0.45	0.57	0.68	0.79	0.91	1.02	1.13	1.25	1.36	1.47	1.59
65	0.42	0.52	0.63	0.73	0.84	0.94	1.05	1.15	1.26	1.36	1.47

The article states that every green aspect must be followed by a yellow interval which warns approaching drivers that the right-of-way is about to be reassigned to a conflicting traffic flow. The yellow interval should be followed by an all-red period which allows vehicles that enter the intersection on yellow to clear before the green aspect is shown to another approach. The proposed methodology would apply equally to through and protected turn phases. The variable should conform to the particular configuration of the intersection and the phase for which timing is being determined. A leading left-turn phase, for example, may have an 85th percentile approach speed of 25 miles per hour which would be used to determine the time the yellow arrow is displayed. Where a concurrent lagging/through phase is involved, the larger of the values generated by the through and left-turn traffic would be used. The author goes on to point out that much work remains to be done to determine the proper selection of values for the many variables and that the ITE Technical Committee 4A-60 "Use and Timing of Signal Change Intervals" is examining not only the validity of these proposals but also identifying ranges and applications for the variables.

2.2.4 May, A.D., Jr., Clearance Interval at Traffic Signals", Highway Research Record 221, Highway Research Board, 1968, pp. 41-71.

From studies in California the author concluded that:

- (1) increasing the amber phase at the urban locations studied from 3 to 5 seconds increased the percentage of motorists operating in an unsafe or an unexpected manner.
- (2) increasing the amber phase at the rural locations studied from 5 to 7 seconds decreased the percentage of motorists operating in an unsafe or an unexpected manner.
- (3) the installation of experimental transverse pavement markings at the urban locations studied slightly decreased the percentages of motorists operating in an unsafe or unexpected manner.

- (4) the installation of experimental transverse pavement markings at the rural locations increased the percentage of motorists operating in an unsafe or unexpected manner.
- (5) the installation of supplemental advance signing location decreased the percentage of motorists operating in an unsafe or unexpected manner.
- (6) future studies extending the work and directed towards providing conclusive evidence for modification improvements will require more accurate measurements than were obtained in the pilot study. Greater photographic detail coupled with more frequent exposures per unit of time will be necessary.

2.2.5 Olson, P.L., and Rothery, R.W., Deceleration Levels and Clearance Times Associated with the Amber Phase of Traffic Signals, Traffic Engineering, April, 1972, pp. 16-19, 62-63.

This paper describes an extension of work carried out by the authors a decade prior to the time at which the paper was prepared. Field studies were undertaken to obtain speed information and driver behaviour on the approach to two different intersections one of which was in an urban environment where the mean speed of vehicles was 33 mph and the second of which was in a suburban environment where the mean speed was 48 mph.

The primary purpose of the work was to obtain more direct measurements of the time required to clear an intersection than had been possible with techniques previously employed. It was thought that the assumptions used in arriving at approximate clearing times in earlier efforts may have resulted in somewhat conservative recommendations. The data from the study (as well as the data reported by another researcher) suggested that the assumptions made in earlier studies were reasonable and amber periods of about 5.5 seconds are realistic in that such amber durations provide a "clearing time" that allows all or nearly all motorists to clear an intersection.

The amber durations employed at the two intersections studied were typical. It was apparent that some cars which would take two seconds in addition to the amber phase to clear the intersection would not stop. At either intersection studied, these vehicles would not have even entered the intersection by the end of the amber (which in most cases is coincident with the onset of green on the cross-street). The implications for safety were obvious.

The data on stopping as a function of deceleration required to stop shows drivers to be more consistent than might have been anticipated. The results indicated that for both intersections studied, the drivers were virtually certain to stop if their required deceleration was less than 8 ft/sec^2 and virtually certain to continue if the decelerations required were in excess of 12 ft/sec^2 . Only in the range from $8\text{-}12 \text{ ft/sec}^2$ was there significant variability in driver response. This implies that drivers are reluctant to expose themselves to the forces corresponding to decelerations in excess of about 12 ft/sec^2 in stopping for a traffic light. Any clearance interval or interpretation of a clearance interval which requires drivers to brake harder, appears to be contrary to normal driver behaviour and therefore unrealistic.

2.2.6 Parsonson, P., and Santiago, A., Design Standards for Timing the Traffic-Signal Clearance Period Must be Improved to Avoid Liability, Compendium of Technical Papers, ITE 50th Annual Meeting, Pittsburgh, August, 1980, pp. 67-71.

This paper warned that the traditional design standards for the timing of the clearance period (yellow plus any all-red) for traffic signals are inappropriate and unreasonable in some important aspects. They can yield values that are too short for safety because they do not correctly take into consideration certain characteristics of drivers, vehicles and the roadway. The authors state that the paper also presents evidence that, in actual practice, traffic engineers often use clearance-period settings that are even shorter than those required by the traditional standards which are themselves inadequate.

The paper discusses the differences between the (U.S.) Manual of Uniform Traffic Control Devices and other professional standards relating to this subject as well as the traffic engineer's duty of care in calculating the yellow and all-red intervals. Also discussed are the influence of assumed deceleration rate, approach grades, design speed and cross-street-entry lag time. A recommended procedure for taking these properly into account is summarized in nomograph form.

The study found that very few of the intersection (through) approaches studied had yellow plus all-red timings that were defensible in court as being based on reasonable deceleration rate, actual grades and the actual range in speeds. The authors determined that about half of the approaches did not even meet the current inadequate standards.

The authors recommended that the sum of the yellow change and all-red clearance intervals be calculated using the following equation:

$$Y + AR = t + \frac{v}{2a+64.4g} + \frac{w+l}{v}$$

where t = perception-reaction time of driver in seconds
(the standard value is 1 second)

v = approach speed in feet per second

a = deceleration rate in feet per second

w = width of intersection

l = length of vehicles (the standard value is 20 feet)

g = percent of gradient divided by 100

The authors point out that the value for "a" should be 10 ft/sec² rather than the 15 ft/sec² normally used and that calculations for both the 85th and 15th percentile speed should be made and the larger of the two values adopted for use. The authors further recommend that no reduction in timing be applied to account

for the time for cross-street traffic to react to the green and enter the intersection.

The yellow portion of the Y+AR should be no less than the sum of the first two terms to permit stopping without entering on the red.

The paper includes nomographs to assist in the calculations.

2.2.7 Ryan, Timothy A., and Davis, Christian F., Driver Use of the All-Red Signal Interval, Paper presented at the Transportation Research Board Annual Meeting, January, 1982.

The purpose of this study was to investigate the theory that drivers use the red signal interval more frequently at intersections with all-red intervals than at intersections without all-red intervals. Data were collected at ten intersections in four New England cities, during both peak and off-peak periods. 2764 signal cycles were observed, during which 1115 vehicles entered the intersection after the start of the red interval.

The data were subjected to statistical analyses, which yielded the following conclusions.

- (1) More drivers ran the red light at intersections with all-red intervals than at intersections which had no all-red intervals.
- (2) The length of the all-red interval appeared to be correlated with driver use of the red interval. (There were, however, four other predictor variables, each of which was more closely correlated with driver use of the red interval than was the length of the all-red interval).
- (3) Apparently drivers did not run the red light longer after the start of the red interval at intersections with all-red intervals than at intersections which had no all-red intervals.

The results of this study must be viewed with caution, since the number of observed locations was relatively small, and since there may be factors influencing driver use of the red interval which were not studied during this project. However, the results do indicate that a problem may exist, and that more research should be done in this area.

2.2.8 Stimpson, W.A., Zador, P.L., and Tarnoff, P.J., The Influence of the Time Duration of Yellow Traffic Signals on Driver Response, ITE Journal, November, 1980, pp. 22-29.

Field studies at two separate intersections - one in Maryland and one in Georgia were undertaken to determine the change in the frequency of potential conflicts when the yellow traffic signal interval was increased. The frequency of potential conflicts at the Maryland site ranged from 12% to 19% with the initial yellow duration of 4.6 seconds. With the extended yellow (6.0 seconds) these were reduced to between 0 and 2%. Thus an increase of 1.4 seconds or about 30% in yellow duration virtually eliminated all potential conflicts at the Maryland site.

At the Georgia site initial conflict percentages were between 63% and 90%. With the extended yellow these were reduced to 19% to 21%. Thus an increase of 32% or 1.6 seconds in yellow duration reduced frequency of potential conflicts at the Georgia site to about 25% of their original frequency. The differences in the potential conflict percentages were attributed to differences between the two sites in terms of geometry, approach speed and traffic volume; however, quantitative relationships that would predict potential conflict frequency in terms of these and possibly, other factors were not established.

The authors concluded that potential intersection conflicts could be virtually eliminated with small increases in the duration of the yellow phase. They point out that, since the numerical relationship between potential conflict (as defined and measured in this study) and the frequency of intersection crashes was currently unknown, it was not possible to estimate the magnitude of the crash loss reduction which may be achieved through the use of slightly longer yellow durations.

The authors point out that there existed no consensus among traffic engineers as to what constitutes an optimal yellow interval under everyday traffic and environmental conditions. Since the influence of change interval on intersection crash frequency has not been investigated, further work is needed to first determine and then to introduce change intervals that will ensure the reduction of avoidable intersection crashes by reducing the frequency of potential intersection conflicts.

2.2.9 Williams, W.L., Driver Behaviour During the Yellow Interval, Transportation Research Record 644, Transportation Research Board, 1977, pp. 75-78.

The author concludes that the minimum length of the clearance interval can be calculated to adequately serve driver's needs and to the law enforcement purposes by using the following equation:

$$Y = R + (V/2a^-) + ((W + L)/V) - (K + (2d/a^+)^{1/2})$$

Where

- R = driver decision and reaction time (1.1/s) *;
- V = 85 percentile approach speed;
- a⁻ = deceleration accepted 85 percent of the time
(2.0 m/s² (6.5 ft/s²))
- W = distance from stop line to the line where the vehicle is shadowed;
- L = length of vehicle (5 m (17 ft) for automobiles);
- K = reaction time of cross-flow traffic (0.4 s) **
- d = distance between vehicles and cross-flow traffic; and
- a⁺ = maximum acceleration of cross-flow traffic
(4.9 m/s² (16.0 ft/s²)).

Or, Y equals decision time plus deceleration time plus clearance time minus cross-flow acceleration time.

* from report by P.L. Olson and R. Rothery. Driver's Response to the Amber Phase of Traffic Signals. General Motors Research Laboratories, Warren, Michigan, 1960.

** from manual by W.S. Smith and F.W. Hurd. Traffic Engineering. McGraw-Hill, New York, 1955.

The author notes that the time calculated from this equation is that used for clearance. This can be provided by the yellow interval in combination with an all-red interval. Using this technique a city or county can standardize the length of the yellow interval (say 3.6 seconds for a 60 second cycle phase) and provide additional clearance time with the all-red interval. If this equation is to be directly applied engineers should conduct field studies in their own locations to determine local values for the unknown parameters.

Engineers should develop probability of stopping versus time charts for their own cities in this way the decision time can be computed by how drivers actually behave in the area being studied. The time deduction for cross-flow acceleration needs to be applied with caution and a value of 0 should be used if "light jumping" is possible.

2.3 Summary of Selected References Flashing Operation of Traffic Signals

2.3.1 Benioff, B., Carson, C., Dock, F.C., A Study of Clearance Intervals, Flashing Operation, and Left Turn Phasing and Traffic Signals Volume 3 - Flashing Operation. U.S. DOT, Report No. FHWA-RD-78-46, May, 1980.

The study was initiated for the purpose of developing recommendations for the use of flashing operation of traffic signals during low volume periods. This study included a literature review, a review of state laws, questionnaires to public officials and to drivers, analytical models of traffic flow and field studies of accidents, conflicts, violations, speed and delay.

Flashing yellow/red operation was found to be desirable for only a limited number of traffic and traffic signal conditions. Flashing red/red operation was not found to be a desirable form of low volume traffic control but considered to have potential when used for emergency operation of traffic signals.

The specific objective of the study was to address the following two questions:

- Under what circumstances should traffic signals be operated in a flashing mode?
- Where flashing operation is used, when should it have a yellow/red pattern and when should it have a red/red pattern?

The report reviews a great deal of the literature which has been written on this subject and this literature has been resummarized in this report.

In a Phoenix study, experience from 1960 when almost all signals outside the central business district (CBD) were on flashing operation from midnight to 6:00 a.m. was described. The City experienced such high accident and severity rates that most of the signals were reverted to regular 24-hour operation, and by 1975 only three signals were left flashing.

In a major study in the District of Columbia, Radelat analyzed 741 signalized intersections that flashed yellow/red along ten heavily travelled arterial routes. The intersections were divided into three groups:

- . Group I - 162 intersections changed from flashing operation to regular operation at night.
- . Group II - 177 intersections that remained in nighttime flashing operation in both the before and after periods and were located no more than two blocks from intersections in Group I.
- . Group III - 402 intersections that remained in nighttime flashing operation in both the before and after periods were located at least two blocks from intersections in Group I.

The times when signals in Group I had been on flashing operation were:

Weekdays	1:00 - 6:00 a.m.
Saturday	3:00 - 6:00 a.m.
Sunday	3:00 - 8:30 a.m.

An investigation of the accidents that occurred during the flashing period was made for every intersection in each group before and after the change of operation in the signals. It was the conclusion of this study that accidents could be reduced by placing signals on regular operation for 24 hours a day, but these conclusions were qualified as follows:

The amount of delay to traffic was not considered in the study. Traffic on both the main and cross streets is stopped more frequently, and for longer periods of time, with signals operating as stop and go devices rather than flashing devices.

Motorists become impatient when stopped by a red traffic signal, especially when there is no traffic moving on the cross street. This could lead to complete disobedience of the traffic signals during the early morning hours when there is little traffic on the cross street.

Another point to bear in mind is the possibility of criminal action. There are cases on record where vehicle operators have been robbed while waiting at a "red" traffic signal.

A study made by the State of Wisconsin concluded, after a "brief statistical analysis" of data from nine intersections, "that, from an accident reduction standpoint, actuated signals should be operated in their normal mode 24 hours a day rather than programmed flashing operation during the nighttime off-peak hours." The study period covered two years of nighttime flashing and two years of nighttime normal mode operation. No other information regarding the study locations was given.

A recent study by Marson went into some detail as to specific factors that affected accidents during nighttime yellow/red flashing operation. Ninety-nine intersections with flashing signal operation from midnight to 6 a.m. (the test

group), and 70 intersections on regular 24-hour, full normal operation (the control group) were analyzed. The difference in overall mean accident rates (per million vehicles) between the test group and the control group was not significant for either the hours of regular operation or the hours of flashing operation. Statistical tests were then used to compare the accidents for intersections stratified according to volume, geometry, speed limits, and signal interconnection. "A correlation of total night accidents versus total entering volume for each of these classifications showed no significant correlation for either the test or control group." The data were then divided into three volume ratios (major street ADT divided by minor street ADT) classifications - greater than 4.0, between 2.0 and 4.0, and less than 2.0 - and it was found that the volume ratio did have a significant effect on accident rates. "For those intersections with a volume ratio greater than 4.0, the test group had a significantly lower accident rate in the "total night", "property damage only" and "rear-end" accident categories. Intersections with a ratio between 2.0 and 4.0 showed that the test group had a greater angle accident rate than the control group." Intersections with a volume ratio less than 2.0 had a higher (but not significantly) angle accident rate under flashing operation but lower (significantly) rear-end accident rate.

For intersections stratified by geometry, where one or both streets were one-way (Type 1), signals with regular operation had a significantly higher rear-end accident rate; where both streets were two-way and undivided (Type 2), the regular group had a significantly higher left-turn accident rate than the flashing group. For intersections with speed limits greater than 40 mph (64 km/h), the regular group had a significantly higher rear-end accident rate; for intersections with a lower limit, the flashing signals had a higher left-turn accident rate. Intersections with interconnected signals had a significantly higher rear-end accident rate under regular operation while those which were isolated did not.

Another research project in the related area of deciding when an intersection should be controlled by a traffic signal as opposed to a two-way STOP sign could not determine a significant relationship between accidents and type of control.

KLD Associates as part of a study distributed a questionnaire to 157 cities, counties, and states asking these agencies to state their criteria for placing signals on flashing operation. The results were as follows:

Of the 97 respondents, 94 answered this question. Of these, 6 indicated that their jurisdiction had no specific criteria for flashing operations. The 88 remaining responses could be divided into four major groupings:

- . 23 (26%) never converted signals to flashing operations (except for emergencies or malfunction);
- . 21 (24%) use the criterion of the 1961 edition of the MUTCD;
- . 25 (28%) used a reduction in traffic volume, (other than 50% or less of the stated traffic volume warrants as specified in the 1961 MUTCD) as the criterion. This was stated in terms of total entering traffic dropping below a fixed value; major and/or minor street traffic reductions or in 6 cases, any reduction below warrant volumes;

- . The remaining 19 (22%) generally indicated the use of criteria not dependent on traffic volumes. This included 9 respondents who implemented flashing operations on a fixed, jurisdiction-wide time schedule and 3 who used comparative delay as the primary criterion.

Of the 64 respondents who utilized flashing operations, 48 cited additional considerations and requirements (such as time of day, type of signal, sight distance, etc.) beyond the primary criteria listed above.

Based on the questionnaire survey, an extensive literature review and a computer simulation study, KLD recommended nine different warrants for installing traffic signals and one warrant for removing existing signals.

Wilbur Smith and Associates undertook a study for the West Virginia Department of Highways on signal warrants for very pronounced peak periods such as occur at large plants during the beginning and ending of shifts. A literature review, questionnaire survey, data from previous studies, field studies of the volume-delay relationship, and a benefit-cost analysis were used in developing warrants. The resulting warrants state that both volume and delay must exceed specified minimum values for at least one hour a day in order to justify a traffic signal. Actuated signals were the recommended type. Of special interest was an identification of volumes at which peak period signals should be placed on flashing operation.

A few recent studies have looked specifically at how placing traffic signals on flashing operation can save energy. As reported by Quan, the City and County of San Francisco recently initiated a program that will eventually have 670 of their 840 signals flashing during low volume periods.

The following were used in the evaluation which estimated reduced delay (514,000 vehicle hours) and reduced consumption of fuel (1,700,000 litres).

- . 0.006 gallons (0.023 litres) of excess fuel required per stop from 25 mph (40 km/h).
- . 0.4 gallons (1.5 litres) of fuel consumed/hour of idling time.
- . Average intersection volume of 150 vph with 75 percent on the major street. (Actual volumes may be higher.)
- . Average delay at a flashing red signal is 5 seconds.
- . Average delay at a normally-operating signal is 10 seconds.
- . There is no delay at a flashing yellow signal.

Quan also found a substantial reduction in electrical energy when signals were put on flashing operation. The power consumed at a flashing signal head was almost 50 percent less than a normally-operating one. Since pedestrian signals are not used during the flashing hours, power consumption is further reduced.

The City of West Covina evaluated the energy conservation effect of setting traffic signals on all-red flashing operation "during early morning, low traffic volume hours." West Covina chose all-red flashing operation so that mode would be available for emergency operation which might occur during periods of high volumes.

The results indicated that total energy usage (vehicle fuel plus electrical) increased under flashing operation due to the increased number of stops required on the major street. It should be noted that if the West Covina data were analyzed assuming flashing yellow, rather than red, on the main street, flashing operation would, as in San Francisco, cause a decrease in total energy consumption. Obviously, the type of flash is important when assessing the effects on resources.

Most of the published literature on flashing operation deals with signals flashing yellow for the major street and red for the minor street.

Probably the most important consideration in choosing the type of flashing operation is safety. Unfortunately, there have been no studies comparing the safety aspects of yellow/red and red/red flashing operation.

Past studies have shown that flashing yellow/red signal operation during off-peak hours can reduce intersection delay, reduce gasoline consumption and conserve electrical energy. In a few situations, such as intersections with a high ratio of major street volume to minor street volume, flashing yellow/red operation also seems to reduce accident rates. In many other situations, however, flashing yellow/red signals significantly increase accident rates, especially for right-angle collisions.

Flashing all-red signals generally cause increased delay and increased fuel consumption that far exceeds the savings in electrical energy needed to operate the signals. Widespread use of all-red flashing would create a situation where an occasional yellow/red flash would be a dangerous violation of driver expectancy.

Two data bases were examined in the FHWA study and confirmed the results of the previous research. Accidents, particularly right-angle accidents, were higher with yellow/red flash than with the regular operation. The first hour after bars closed (2-3 a.m.) was the most hazardous driving time in San Francisco. Intersections with a main street/side street volume ratio of less than 3 were most affected by flashing operation. Accidents for flashing red/red operation were no higher than for regular operation.

Both rear end and crossing conflicts were higher with flashing yellow/red than with regular operation. Violations of a flashing red signal were higher than for a solid red signal. The speeds, on approaches changed from regular to flashing operation, increased significantly; on approaches changed to a flashing red they decreased slightly.

The conclusions as stated in this report are as follows:

1. Flashing yellow/red operation may be used when two-way traffic volumes on the main street are below 200 vehicles per hour.

2. Flashing yellow/red operation may be used where the two-way main street volume is greater than 200 vehicles per hour provided the ratio of main street to side street volume is greater than 3.
3. At locations that flash yellow/red, the accident pattern should be monitored. Signal operation should be changed to regular operation if the accident pattern during the flashing period meets or exceeds the following guidelines:
 - . a short-term rate of 3 right-angle accidents in one year;
 - . a long-term rate of 2.0 right-angle accidents per million entering vehicles during flashing operation if the rate is based on 3 to 5 observed right-angle accidents.
 - . a long-term rate of 1.6 right-angle accidents per million entering vehicles during flashing operation if the rate is based on 6 or more observed right-angle accidents.
4. Flashing red/red operation should not be used as an alternative to regular operation of a signal during early morning, low volume periods.

The following recommendations were not validated by this study but, based on the conventional wisdom of traffic engineers, seemed worthy of mention:

5. It seems reasonable that flashing yellow/red operation not be used where side street drivers have a restricted view of approaching main street traffic.
6. In areas where stopped motorists are subject to assault, flashing yellow/red operation may be considered where it otherwise should not be.
7. The use of flashing red/red operation seems reasonable when it is needed for emergency signal operation, pre-emption by trains or emergency vehicles, or prior to turning on a signal at an intersection controlled by a four-way STOP sign.

The report goes on to point out that there are still some unanswered questions about flashing operation. What is the best right-of-way rule for a flashing signal? Are there certain classes of intersections for which flashing should be prohibited? Several classes were examined in the study, but sample size of some classes was small. Intersections of freeway off-ramps were barely examined in the current study. Perhaps time of night is important: The San Francisco data implied the accident rate was highest in the hour after bars closed, but these results need confirmation in other cities.

The report suggests that, possibly, a fruitful area of future research would be determining why accidents are higher with flashing yellow/red operation. In several places in this report it was speculated that the increase in accidents was due to drivers having difficulty in judging when it was safe to proceed. If this speculation were confirmed and the actual driver decision process identified,

possible countermeasures, other than just reverting to regular operation, might be developed.

2.3.2 Goldblatt, R.B., KLD Associates Incorporated, Effect of Flashing Beacons on Intersection Performance. Transportation Research Record 644.

The paper presents the results of a study on the operational effects of intersection and advanced warning devices used both on a continuous basis and through vehicle actuation. Five intersections and three advanced warning devices were tested at an intersection in Maine. The conclusions from the study were:

1. the use of actuated "WHEN FLASHING - VEHICLE CROSSING" signs and beacons along the main street approaches causes a reduction in speed dispersion along the approach, which is more pronounced on the approach with poor sight distance.
2. the installation of continuously flashing intersection beacons without "WHEN FLASHING - VEHICLE CROSSING" advisory warning signs had little or no effect on the main street speed distribution,
3. a continuously flashing beacon encouraged lower vehicle speeds along the 'STOP' approach but not if the beacon is actuated.

The use of advance warning beacons in conjunction with a "STOP AHEAD" sign was found to reduce speed variance. In addition, vehicles began the braking manoeuver farther from the intersection; however, these results become less significant when any beacon is used at the downstream intersection probably because the intersection beacon flashes red while the "STOP AHEAD" beacon flashes yellow.

2.3.3 Transportation Energy Management Program (Ontario), Traffic Management Measures to Reduce Energy Consumption.

This report presents information on potential user cost savings resulting from the use of a flashing operation at intersections.

The report identifies guidelines extracted from the U.S. Department of Transportation Report entitled "Criteria for Removing Traffic Signals, Interim Report" and also presents fuel consumption estimates for different forms of intersection control.

Although the report indicates the traffic volume conditions under which flashing yellow on the main street and flashing red on the side street may be used, other guidelines identified suggest that flashing yellow on the main street and red on the side street should not be used as an alternative to regular operation of a signal during early morning low-volume periods and should not be used where side street drivers have a restricted view of approaching main street traffic. The use of flashing red on the main street and red on the side street is most appropriate for emergency signal operation, pre-emption by trains or emergency vehicles or initiating signal control at an intersection controlled by a four-way STOP sign.

3.0 SUMMARY OF RESPONSES TO QUESTIONNAIRE

In order to establish the current practices in the municipalities and the provinces in Canada, questionnaires were sent to 178 agencies including all provinces and all municipalities in which, according to information provided by provincial authorities, there were 10 or more traffic signals in operation in the municipality.

The mailing list for the questionnaires was established through the cooperation of the provincial representatives.

There were 80 questionnaires returned; however, not all respondents provided information with respect to each of the various components of the questionnaire.

A copy of the questionnaire is provided in Appendix B.

The tabulations of the responses are provided in Appendix C. In this section of the report a brief discussion of the responses to each of the questions is provided.

Part A of the questionnaire sought information on the types of left-turn phasing in use, left-turn phase timing, vehicle clearance intervals and flashing operation of traffic signals.

3.1 Basis for Determining the Need for a Left-Turn Phase (Question 1A)

Of the 79 agencies responding to this question, twenty-six indicated that the criterion "more than two left-turning vehicles per cycle" was used as the basis for determining the need for a left-turn phase, twenty-nine agencies used the Highway Capacity Manual and forty-six agencies used field observations. In many cases 2 or more of the foregoing were used and, in addition, there was a variety of other criteria for determining the need for a left-turn phase. In this latter regard, the notes referred to in Table 1 provide additional information.

3.2 Method Used to Determine Left-Phase Time (Question 1B)

A variety of methods are used to determine left-turn phase time and these can be found, in abbreviated form, in Table 2 which summarizes the 71 responses received to this question. No one method appears to achieve any prominence in its use and a variety of methods are, in fact, in use for this purpose.

3.3 Portion of "Advanced Green" Left-Turn Phase Dedicated to a Clearance Interval (Question 1C)

Of the 76 agencies responding to this question, only 10 indicated that they did not use a clearance interval. As might be expected, intersection geometry is used, obviously in the context of calculating the length of the clearance interval, more than any other basis. It is likely that this factor is used in conjunction with the application of the table in the Manual of Uniform Traffic Control Devices for

Canada which was also a significant response. A large group of agencies indicated the use of an absolute value ranging from 2 seconds to 7 seconds while a number of agencies indicated that clearance interval time is determined from field observations.

3.4 Type of Left-Turn Phasing Used and Guidelines Applied in the Selection of the Type of Phasing (Question 1D)

Of the 75 agencies responding to this question, 93% indicated the use of an advance green with 28% indicating the use of an extended green. In 48% of the responses, the use of a leading simultaneous left-turn was indicated while in 20% of the responses a lagging simultaneous left-turn phase was indicated as being used. Exclusive Protected left-turn phasing was indicated as being used in 52% of the responses while in 37% of the responses, the use of a separate/protected left turn phase was indicated as being in use.

The guidelines applied in the selection of the type of phasing are provided, in summary form, in the notes to Table 4.

3.5 Vehicle Clearance Interval Determination (Question 2A)

Seventy-four agencies responded to this question with 32 agencies indicating the use of the Canadian Manual on Uniform Traffic Control Devices, 10 indicating the use of the Ontario Manual of Uniform Traffic Control Devices, 13 indicating the use of the Transportation and Traffic Engineering Handbook and 5 indicating the use of the Ontario Ministry of Transportation and Communications Manual of Signal Timing. Some agencies used a combination of the foregoing. In other agencies a variety of methods is described and these are summarized in the notes to Table 5.

3.6 Use of "All-Red" Vehicle Clearance Interval (Question 2B)

Of the 77 agencies providing a response, 33 indicated the use of an "all-red" vehicle clearance interval at selected intersections assessed individually while 40 indicated that the use of the "all-red" vehicle clearance interval is now or will be applied at all intersections. Some agencies provided comments in the form of notes which have been summarized and included as an attachment to Table 6.

3.7 Flashing (Red-Amber) Operation of Traffic Signals (Question 3)

Of the 79 agencies providing information in this subject area, 27 indicated that this mode of operation is not used at any intersections and 20 agencies indicated that it was used at less than 5% of the intersections.

For those jurisdictions in which the flashing (red-amber) operation of traffic signals is used, 19 indicated its use of the CBD, 19 indicated its use in the inner city area, 20 indicated its use in the suburban areas and 9 indicated its use in the rural areas. Thirty-eight of the agencies assessed intersections on an individual basis in determining the use of this mode of operation while 10 agencies indicated that intersections are assessed on a system/area basis.

Part B of the questionnaire sought information on current practices related to left-turn signal phasing and displays. In light of the recent trend toward the application of signal displays which are unique to a particular intersection design and type of phasing, a variety of possible intersection configurations were provided as part of the questionnaire. Respondents were asked to select, from among the categories, the various intersection configurations with which left-turn phasing is applied in their jurisdiction, indicate on the basic intersection sketch the locations at which signal heads are mounted and then indicate the signal indications which are displayed for each phase interval.

The variety of responses received defies summary in a simple form. Suffice it to say, there are numerous combinations of phasing, displays, clearance intervals and intersection geometry.

Summarized in the following are the indications used together with the type of phasing for which the indication is used and the type of clearance interval related to the type of phasing.

**Type of Indications
Flashing Green Ball**

	Clearance Interval Indication					
	Green	Amber	Amber and Green	Amber and Red	All Red	None
Advanced Green L.T.	X					
Extended Green L.T.		X		X		
Separate Protected L.T.					X	

**Type of Indications
Flashing Green Arrow with Solid Green Ball**

	Clearance Interval Indication					
	Green	Amber	Amber and Green	Amber and Red	All Red	None
Advanced Green L.T.	X	X	X			X
Extended Green L.T.		X		X		
Separate Protected L.T.		X			X	

Type of Indications
Flashing Green Arrow with Flashing Green Ball

	Clearance Interval Indication					
	Green	Amber	Amber and Green	Amber and Red	All Red	None
Advanced Green L.T.	X					

Type of Indications
Solid Green Arrow with Solid Green Ball

	Clearance Interval Indication					
	Green	Amber	Amber and Green	Amber and Red	All Red	None
Advanced Green L.T.	X	X				X
Extended Green L.T.		X				
Separate Protected L.T.		X			X	

Type of Indications
Flashing Green Arrow with Solid Red Ball

	Clearance Interval Indication					
	Green	Amber	Amber and Green	Amber and Red	All Red	None
Advanced Green L.T.	X					
Leading Simultaneous L.T.					X	X
Lagging Simultaneous L.T.		X				

Type of Indications
Solid Green Arrow with Solid Red Ball

	Clearance Interval Indication					
	Green	Amber	Amber Arrow	Amber and Red	All Red	None
Combination of Leading Simultaneous L.T. and Advanced Green	X					
Leading Simultaneous L.T.		X	X		X	X
Lagging Simultaneous L.T.		X			X	
Leading Exclusive Protected L.T.				X	X	
Extended Exclusive Protected L.T.		X				

Type of Indications
Flashing Green Arrow

	Clearance Interval Indication					
	Green	Amber	Amber and Green	Amber and Red	All Red	None
Leading Simultaneous L.T.		X				
Extended Green L.T.		X				
Lagging Simultaneous L.T.		X				
Leading Exclusive Protected L.T.		X				
Lagging Exclusive Protected L.T.		X				
Advanced Exclusive Protected L.T.		X				
Extended Exclusive Protected L.T.		X				

Type of Indications
Solid Green Arrow

	Clearance Interval Indication					
	Green	Amber	Amber Arrow	Amber and Red	All Red	None
Advanced Green L.T.						X
Leading Simultaneous L.T.		X			X	
Extended Green L.T.		X				
Lagging Simultaneous L.T.						X
Separate Protected L.T.		X			X	
Leading Exclusive Protected L.T.		X	X	X	X	
Lagging Exclusive Protected L.T.		X	X			
Advanced Exclusive Protected L.T.			X			
Extended Exclusive Protected L.T.			X	X		

Type of Indications
Solid Green Arrow with Solid Red Ball
Followed by Solid Green Arrow Solid Green Ball

	Clearance Interval Indication					
	Green	Amber	Amber and Green	Amber and Red	All Red	None
Combination of Leading Simultaneous L.T. and Exclusive Protected L.T.						X

**Type of Indications
Flashing Green Arrow Followed by Flashing
Green Arrow with Solid Green Ball**

		<u>Clearance Interval Indication</u>					
		Green	Amber	Amber and Green	Amber and Red	All Red	None
Combination of Leading Simultaneous L.T. and Advanced Green L.T.						X	

In the summaries provided, no attempt has been made to indicate the relative weight (or magnitude of the extent of use) for any particular combinations; however, generally speaking, the flashing green ball with a solid green ball clearance interval is used extensively. To a somewhat lesser extent but still significant is the use of the flashing green arrow with a solid green ball normally utilizing the green ball alone for the clearance interval and, as well, a solid green arrow with a solid green ball also using the green ball for the purpose of the clearance interval.

As might be expected the foregoing represent the prominent displays used for advanced green phasing. This type of phasing, it will be recalled, is used by 92% of the agencies which responded to the questionnaire.

The use of the solid green arrow with the solid red ball represents a type of display which is used with some degree of consistency although without any particular consistency with regard to the type of clearance interval. The only other type of display which was used with any degree of prominence was the solid green arrow with an amber clearance interval.

The remaining displays are used without any apparent degree of consistency.

4.0 RULES OF THE ROAD

The Roads and Transportation Association of Canada and the Canadian Conference of Motor Transport Administrators are collaborating on a study of the uniformity of the rules of the road in the Provinces. The portion of the summary of the rules of the road which is relevant to traffic signals is provided in Appendix D.

APPENDIX A
LISTS OF SELECTED REFERENCES

LEFT TURN PHASING AND DISPLAYS

LIST OF REFERENCES

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VEHICLE CLEARANCE TIMING

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**FLASHING OPERATION
OF
TRAFFIC SIGNALS**

LIST OF REFERENCES

SUMMARIZED

1. Benioff, B., Carson, C., Dock, F.C., A Study of Clearance Intervals, Flashing Operation, and Left Turn Phasing and Traffic Signals Volume 3 - Flashing Operation. U.S. DOT, Report No. FHWA-RD-78-46, May, 1980.
2. Goldblatt, R.B., KLD Associates Incorporated, Effect of Flashing Beacons on Intersection Performance. Transportation Research Record 644.
3. Transportation Energy Management Program, Traffic Management Measures to Reduce Energy Consumption.

SUMMARIZED AS PART OF REFERENCE 1 ABOVE

4. Marson, Joseph A., A Comparison of Accident Experience at Intersections with Flashing and Regular Traffic Signal Control During Low-Volume Time Periods, M.S. Thesis, Department of Civil Engineering, Michigan State University, 1976.
5. Pharo, Thomas J., and Surti, Vasant H., Analysis of Flashing Traffic Signals as a Method for Conserving Fuel, Paper prepared for the 56th Annual Meeting, Transportation Research Board, August 1976.
6. Quan, Harvey, San Francisco's Experience with Flashing Signals, Western ITE 29, No. 1 (August-September 1975), 3-4.
7. Radelat, Guido, Accident Experience as Related to Regular and Flashing Operation of Traffic Signals, Staff Report, District of Columbia Department of Highways and Traffic, June, 1976.

UNSUMMARIZED

8. Bleyl, R.L., Speed - Profiles Approaching a Traffic Signal, Highway Research Record, HRB N384, June, 1972, pp 17-23.
9. Carlsen, Thomas E., Statistical Analysis, Before and After Accident Study, Programmed Flashing Versus 24-Hour Normal Signal Operation, Departmental Correspondence, Wisconsin State Department of Transportation, May 1974.
10. Perkins, Stuart R., and Harris, Joseph I., Traffic Conflict Characteristics -- Accident Potential at Intersections, Highway Research Record 225, Highway Research Board, Washington, D.C., 1968, 35-43.
11. Reilly, W.R., Gardner, C.C., and Kell, J.H., A Technique for Measurement of Delay at Intersections, Volume 3, User's Manual, Report FHWA-RD-76-137, Federal Highway Administration, Washington 1976.

APPENDIX B
QUESTIONNAIRE

DEFINITIONS RELATED TO LEFT TURN PHASES

In order to ensure consistency throughout this project, it is essential that the terminology which is used is well defined. In this regard the following definitions are provided.

General

1. Permissive Left Turns

The left turn driver has the opportunity to turn, permissibly, when adequate gaps appear in opposing traffic. The driver must yield the right-of-way to opposing vehicular and pedestrian traffic.

2. Protected Left Turns

The left turn driver is directed to turn left in a protected manner through a signal display and left turn traffic has the right-of-way over the opposing vehicular and pedestrian traffic.

Protected/Permissive Left Turn Phasing

The left turn driver is first directed to turn left in a protected manner through a signal display and then given the opportunity to turn, permissibly, when adequate gaps appear in opposing traffic, through the display of a circular green. This can be provided in the following forms:

Advanced Green - a protected left turn, for traffic entering the intersection from one approach only, is provided and is followed by permissive left turns during an interval in which other traffic in the same direction and in the opposing direction is permitted to enter the intersection.

Leading Simultaneous Left Turn - a protected left turn, for traffic from opposing directions entering the intersection simultaneously, is provided and is followed by permissive left

turns during an interval in which other traffic in the same direction and in the opposing direction is permitted to enter the intersection.

Permissive/Protected Left Turn

The left turn driver is first given the opportunity to turn, permissibly, when adequate gaps appear in opposing traffic and then directed to turn left in a protected manner through a signal display. This can be provided in the following forms:

Extended Green - Permissive left turns (during an interval in which other traffic in the same direction and in the opposing direction is permitted to enter the intersection) are followed by protected left turns, entering the intersection from one approach only.

Lagging Simultaneous Left Turns - Permissive left turns (during an interval in which other traffic in the same direction and in the opposing direction is permitted to enter the intersection) are followed by protected simultaneous left turns, entering the intersection from opposing approaches.

Exclusive/Protected Left Turns

Left turns, entering the intersection from one or opposing approaches simultaneously, are directed to proceed only through the display of a green arrow.

Separate Protected Left Turn

All traffic, including the left turns, is directed to enter the intersection from one approach at a time while the traffic on all other approaches is stopped.

PART A

**LEFT TURN PHASE TIMING
VEHICLE CLEARANCE INTERVAL TIMING
FLASHING (AMBER-RED) OPERATION OF
TRAFFIC SIGNALS DURING LOW TRAFFIC VOLUME PERIODS**

This part of the questionnaire seeks information on the current practices being applied with respect to the above subject areas.

Where insufficient space has been provided for your reply, please provide the information on an attachment.

Provision has been made for including any general remarks related to these subject areas and comments in this regard would be most welcome.

1. (a) The ~~need~~ for a left-turn phase is based on:

- ☐ More than two left turning vehicles per cycle
- ☐ Highway Capacity Manual i.e. left turns exceed a value of $(1200 \times G/C)$ - opposing through volume)
- ☐ Field observation
- ☐ Other (specify) _____

(b) Left turn phase **time** is determined using:

(c) Normally, when an "advanced green" left-turn phase is utilized part of this phase is dedicated to a clearance interval

(i) Is such a clearance interval used? ☐ Yes ☐ No

(ii) Length of clearance interval, if used _____

(iii) Clearance interval **time** is determined using: _____

(d) Please indicate below (or attach a copy of, if more convenient) the guidelines which are used in the selection of left-turn phasing for the following types of phasing.

(i) Advanced Green _____

(ii) Leading Simultaneous _____
Left-Turn _____

(iii) Extended Green _____

(iv) Lagging Simultaneous Left-Turn _____

(v) Exclusive/Protected Left-Turn _____

(vi) Separate/Protected Left-Turn _____

2. (a) The vehicle clearance interval (amber or amber plus all red) is determined using:

☐ Canadian Manual of Uniform Traffic Control Devices (Table B 3.16)

☐ Transportation and Traffic Engineering Handbook (Page 814-816)

☐ Other (specify) _____

- (b) An 'All Red' vehicle clearance interval is incorporated in the vehicle clearance interval at:

☐ Selected intersections assessed individually

☐ All intersections (or will be used at all intersections)

Comments or experience with "All Red" vehicle clearance interval

3. (a) Flashing operation (red - amber) of traffic signals

- ☐ This mode of operation is not used at any intersections
- ☐ This mode of operation is used however it is confined to less than 5% of all signal controlled intersections

(b) This mode of operation is used extensively and is applied at:

	<u>Day time</u>	<u>Night time</u>
CBD intersections	☐	☐
Inner city intersections	☐	☐
Suburban intersections	☐	☐
Rural type intersections	☐	☐

(c) In determining the use of this mode of operation

- ☐ Each intersection is assessed individually
- ☐ Intersections are selected on system/area basis

4. Please indicate the criteria used to determine the need for flashing operation (red-amber) of traffic signals

5. Other Remarks

6. Total number of traffic signals

Information provided by:

Name:

Municipality/Province:

PART B

This part of the questionnaire seeks information on **current** practices related to left-turn signal phasing and displays. **Do not include information on discontinued phasing practices and displays even though such installations may still exist in your jurisdiction.**

LEFT TURN SIGNAL PHASING AND DISPLAYS

There has been a trend recently towards the application of signal displays which are unique to a particular intersection design and type of phasing. In order to ensure that all of the current practices in this regard are considered and that minimal effort is required, on the part of the respondents to this questionnaire, in providing this information, a variety of possible intersection configurations is illustrated on the following pages. The intersection configurations have been categorized as follows:

Intersection Configuration

<u>Category</u>	<u>Figures</u>	<u>Page Colours</u>
Undivided	U-1 to U-6	Yellow
Divided with conventional narrow medians	D-1 to D-6	Green
Divided with double left turn lanes	D-7 and D-8	Tan
Divided with wide medians	D(WM)-1 and D(WM)-2	Blue

Within each of these categories there are variations (e.g. with an opposing left turn lane, with no opposing left turn lane) which should cover all of the typical intersection configurations. If there is an unique configuration which should be considered, copies of the basic forms have been provided on pink pages on which the intersection configuration can be sketched and other relevant information can be provided.

The sketch portrays a perspective view of the various intersection configurations. The principal mounting poles are shown for the far right and far left corners of the intersection and on the median (where the sketch includes a median). The other poles and signal heads are illustrated, by dashed lines, solely to enhance the impression of the intersection. The intersection can be considered as being a T-intersection, if appropriate, by merely ignoring one of the "side street" approaches. Regardless of the actual orientation of the intersections in your jurisdiction, always consider that the street with the separate left turn phase is in a north-south orientation and the direction of travel favoured by a left turn phase is northbound traffic. The questionnaire seeks information mainly on the signal heads which would be "facing south" (i.e. for northbound traffic) but also on the signal heads "facing north"; although information on the relative physical location of these "facing north" signal heads is not required.

The following three steps should be followed in completing the questionnaire:

- (1) Select from among the categories, the various intersection configurations with which left turn phasing is applied in your jurisdiction.
- (2) Add to the basic intersection sketch the locations at which the signal heads are mounted. It is essential that the relative positions of the signal heads be shown with considerable degree of representativeness. These would be the signal heads as viewed by a driver approaching the intersection in a northbound direction (i.e. the "SIGNAL HEADS FACING SOUTH").

Give each signal head added to the sketch a code number (i.e. 1, 2, 3 or 4).

Enter the number in the corresponding rectangular shaped box below the words "SIGNAL HEADS FACING SOUTH".

(3) For each phase interval separately indicate the

- traffic movements that are permitted (for movements which are permitted by a green arrow indication use a broken line (i.e. ---->))
- the pedestrian movements that are permitted
- the individual signal indications which are illuminated in each of the identified "SIGNAL HEADS FACING SOUTH". Either "white out" or cross out the signal indications which would not exist in a particular signal head.
- the indications which are illuminated in pedestrian heads (use "W" for the "WALK" or pedestrian symbol and "DW" for the "DON'T WALK" or hand symbol)
- the indications which are illuminated in the "SIGNAL HEADS FACING NORTH" i.e. signal heads facing the opposing (i.e. southbound) traffic. In this regard it is recognized that the signal displays facing opposing traffic may be of more than one array of lens indications but not likely of more than two arrays of lens indications. Where opposing traffic faces one array only, use one of the two arrays provided.

(4) To the left of each of the illustrated signal heads, indicate the lens size for each indication (200 = 200 mm (8") and 300 = 300 mm (12")). These sizes need be indicated on only the first series of illustrated signal heads (see the pink coloured page which follows).

(5) Please indicate on any of the figures, those intersection configurations which have caused the greatest concern in the operation of the phasing and the displays. A brief comment can be added below the word "PROVINCE".

In order to provide further assistance in understanding the information which is required, a sample of a completed form is provided on the pink sheet which follows this page.

Please return all of the attached intersection configuration forms. If a particular form does not apply in your municipality/jurisdiction, write the words "Not Applicable" across the form. If the signal displays and phasing are the same for two or more intersection configurations, it is only necessary to complete one form. For the other intersection configuration simply write across the form "SAME AS ON FIGURE __".

INTERSECTION CONFIGURATION DIVIDED

Opposing left turn lanes
encroaching left of centre line
(partially offset)

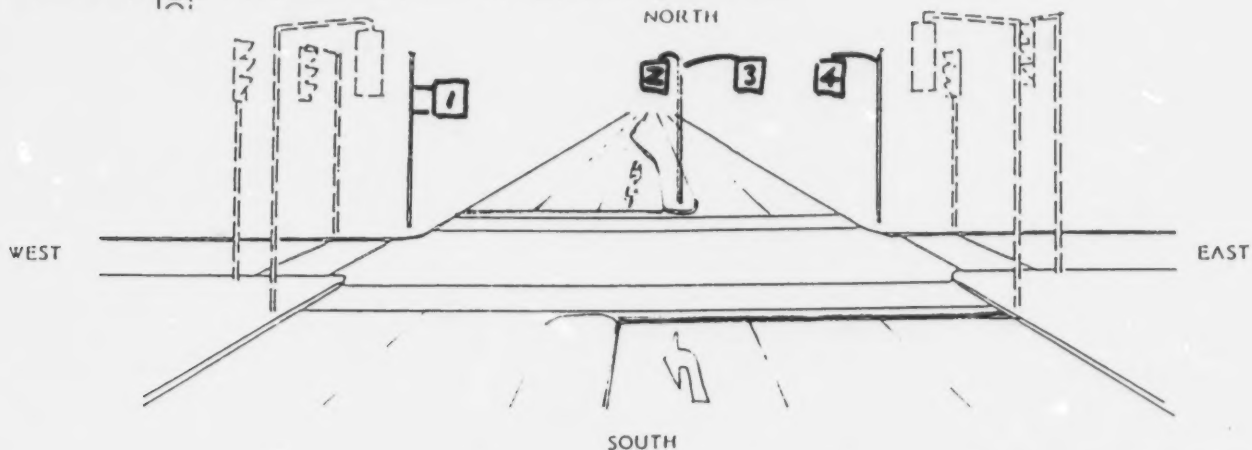
FIGURE D-6

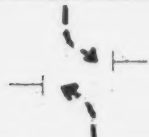
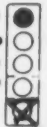
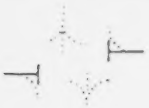
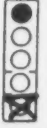
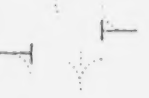
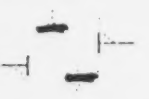
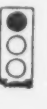
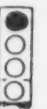
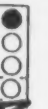
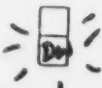
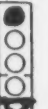
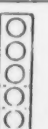
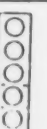
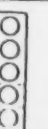
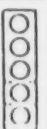
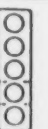
MUNICIPALITY ANYTOWN

PROVINCE _____

Indicate thusly  if a particular indication is in the flashing mode.

Indicate thusly  P if a particular indication is a 3M optically programmed section



Phases/ Traffic Movements	Pedestrian Movements	SIGNAL HEADS FACING SOUTH				Pedestrian Heads N-S Movement	SIGNAL HEADS FACING NORTH	
		1	2	3	4			
		300 200 300 	200 200 300  P	300 200 200 300 	300 300 300 300 		300 200 200 	300 200 200 300 
								
				LT 				
								
								
								

INTERSECTION CONFIGURATION UNDIVIDED
No separate left turn lane
Opposing left turn prohibited

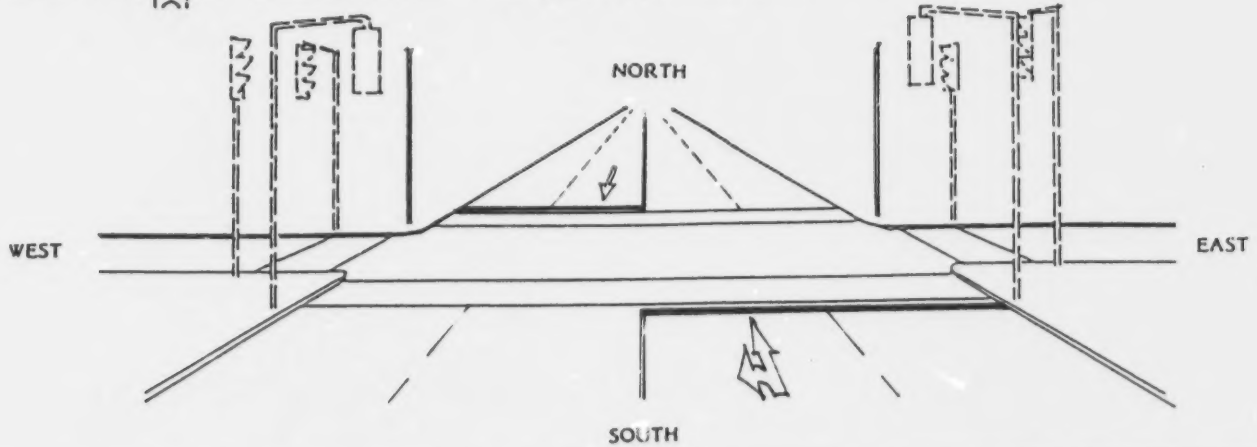
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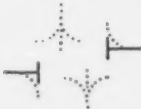
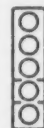
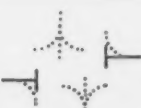
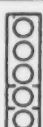
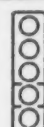
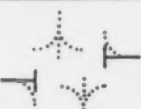
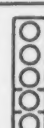
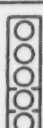
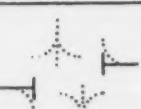
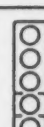
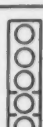
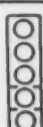
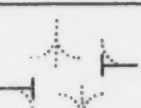
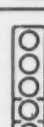
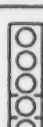
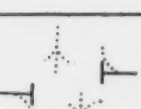
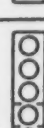
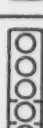
MUNICIPALITY _____

PROVINCE _____

Indicate thusly  if a particular indication is in the flashing mode.

Indicate thusly  if a particular indication is a 3M optically programmed section



Phases/ Traffic Movements	Pedestrian Movements	SIGNAL HEADS FACING SOUTH				Pedestrian Heads N-S Movement	SIGNAL HEADS FACING NORTH	
								
								
								
								
								
								
								

INTERSECTION CONFIGURATION UNDIVIDED
No separate left turn lane
Opposing left turn allowed

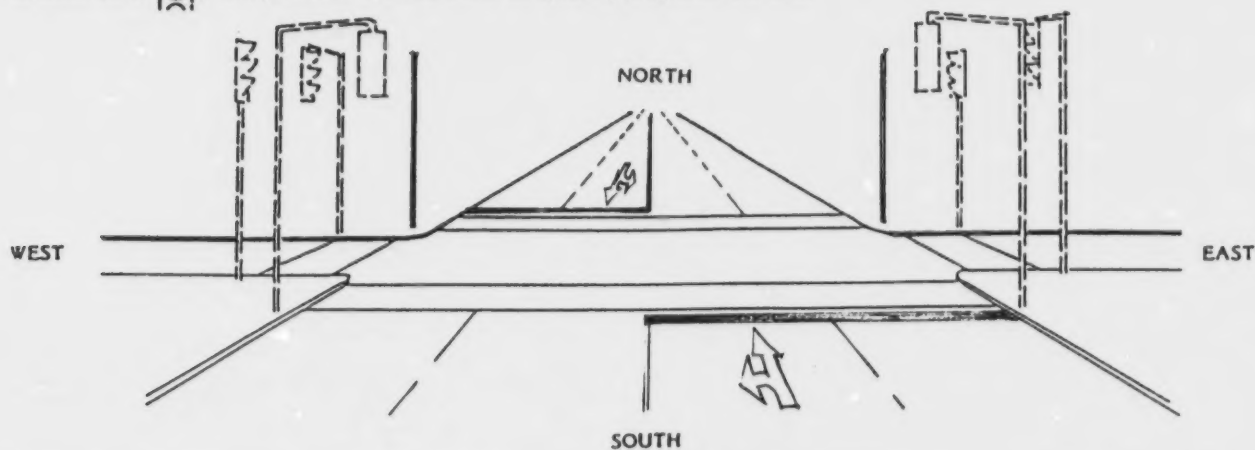
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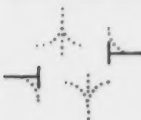
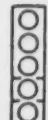
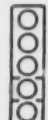
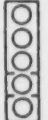
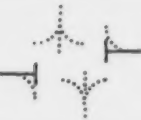
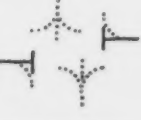
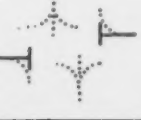
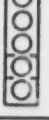
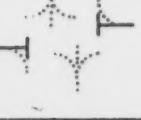
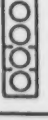
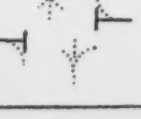
MUNICIPALITY _____

PROVINCE _____

Indicate thusly  if a particular indication is in the flashing mode.

Indicate thusly  P if a particular indication is a 3M optically programmed section



Phases/ Traffic Movements	Pedestrian Movements	SIGNAL HEADS FACING SOUTH				Pedestrian Heads N-S Movement	SIGNAL HEADS FACING NORTH	
								
								
								
								
								
								
								

INTERSECTION CONFIGURATION UNDIVIDED
Separate left turn lane designated
Opposing left turn prohibited

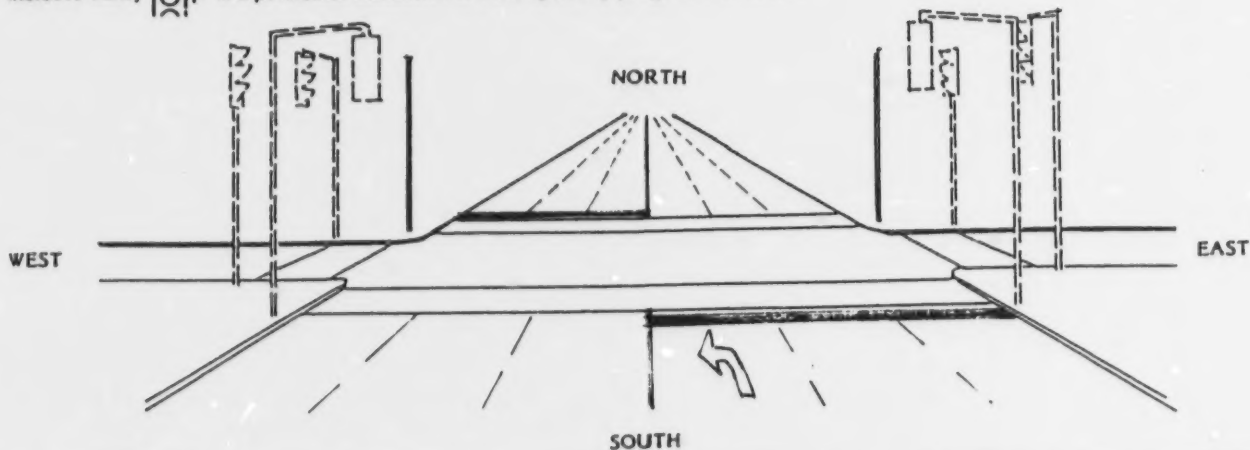
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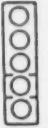
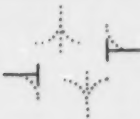
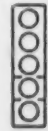
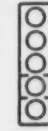
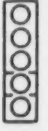
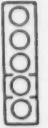
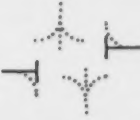
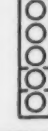
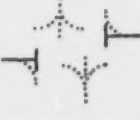
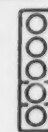
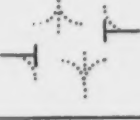
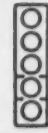
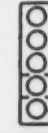
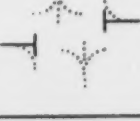
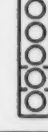
MUNICIPALITY _____

PROVINCE _____

Indicate thusly  if a particular indication is in the flashing mode.

Indicate thusly  if a particular indication is a JM optically programmed section



Phases/ Traffic Movements	Pedestrian Movements	SIGNAL HEADS FACING SOUTH				Pedestrian Heads N-S Movement	SIGNAL HEADS FACING NORTH	
								
								
								
								
								
								

INTERSECTION CONFIGURATION UNDIVIDED

Left turn lanes designated -
offset from each other

Opposing left turn allowed

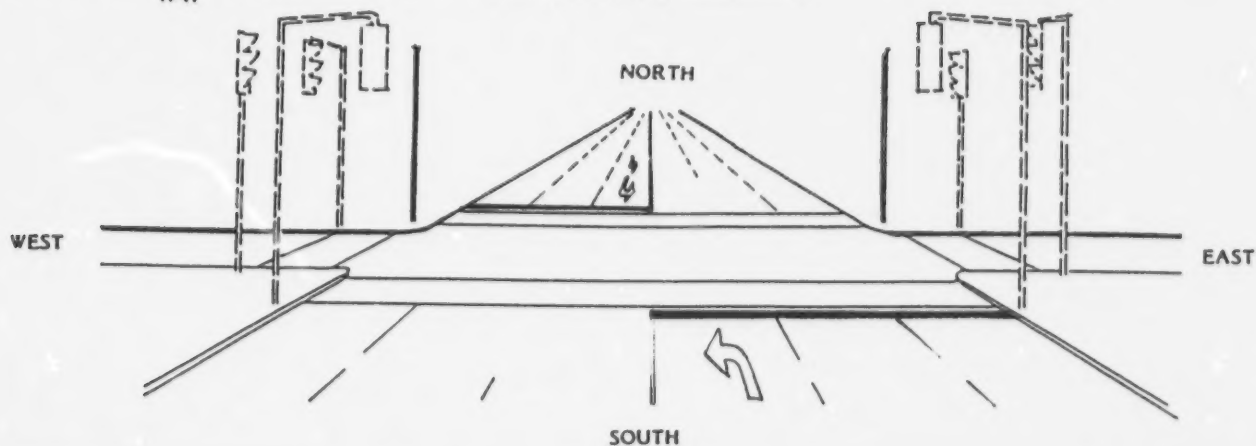
FIGURE U-4

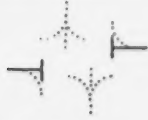
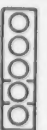
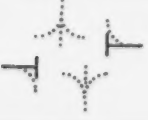
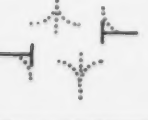
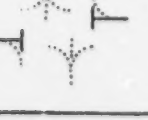
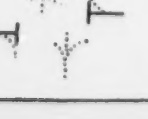
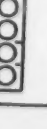
MUNICIPALITY _____

PROVINCE _____

Indicate thusly  if a particular indication is in the flashing mode.

Indicate thusly  if a particular indication is a 3M optically programmed section



Phases/ Traffic Movements	Pedestrian Movements	SIGNAL HEADS FACING SOUTH				Pedestrian Heads N-S Movement	SIGNAL HEADS FACING NORTH	
								
								
								
								
								
								
								

INTERSECTION CONFIGURATION UNDIVIDED
Left turn lane encroaching left of centre line
without opposing left turn lane

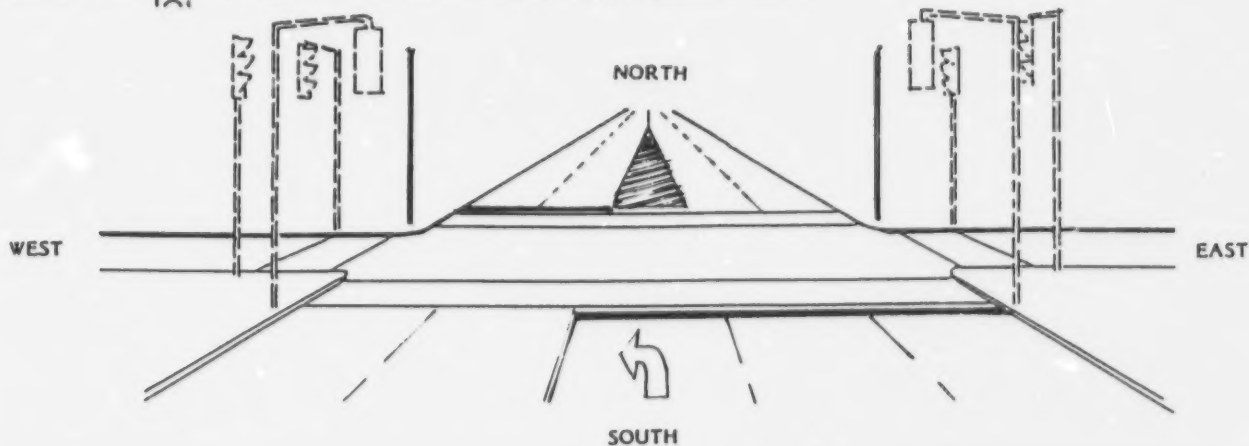
FIGURE U-5

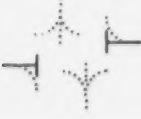
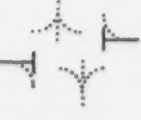
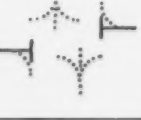
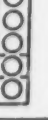
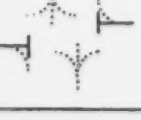
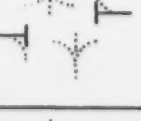
MUNICIPALITY _____

PROVINCE _____

Indicate thusly  if a particular indication is in the flashing mode.

Indicate thusly  if a particular indication is a 3M optically programmed section



Phases/ Traffic Movements	Pedestrian Movements	SIGNAL HEADS FACING SOUTH				Pedestrian Heads N-S Movement	SIGNAL HEADS FACING NORTH	
								
								
								
								
								
								
								

INTERSECTION CONFIGURATION UNDIVIDED
Opposing left turn lanes
encroaching left of centre line

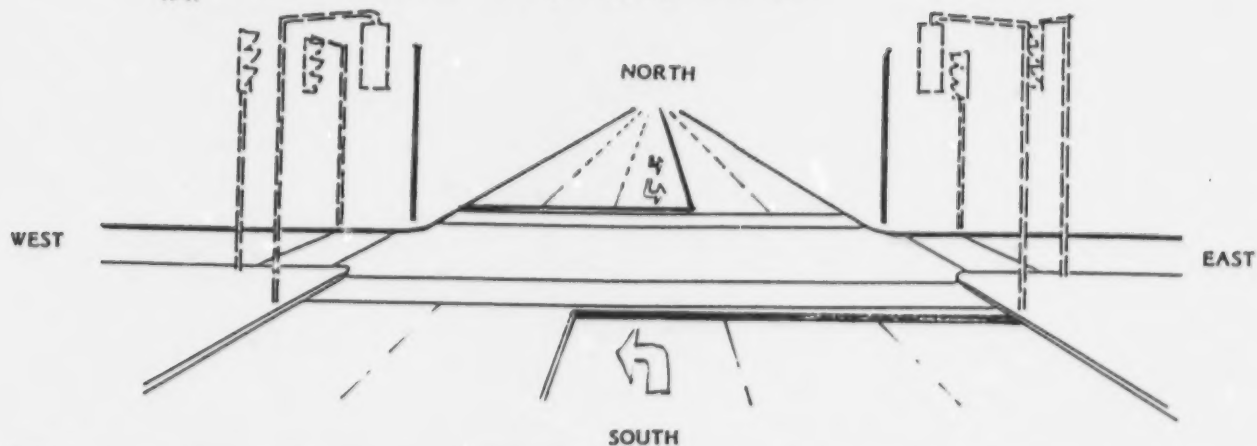
FIGURE U-6

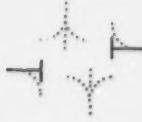
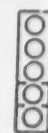
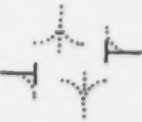
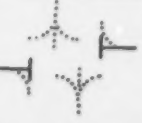
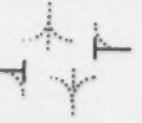
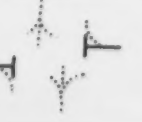
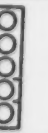
MUNICIPALITY _____

PROVINCE _____

Indicate thusly  if a particular indication is in the flashing mode.

Indicate thusly  if a particular indication is a 3M optically programmed section



Phases/ Traffic Movements	Pedestrian Movements	SIGNAL HEADS FACING SOUTH				Pedestrian Heads N-S Movement	SIGNAL HEADS FACING NORTH	
								
								
								
								
								
								
								

INTERSECTION CONFIGURATION DIVIDED
No separate left turn lane
Opposing left turn prohibited

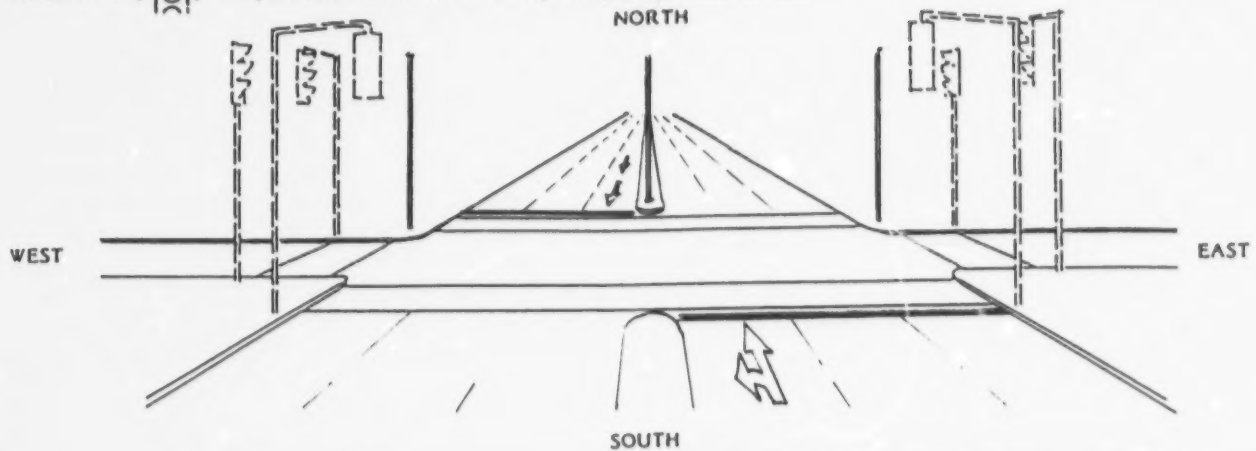
FIGURE D-1

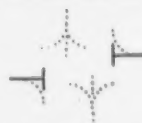
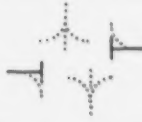
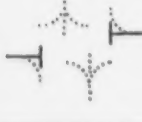
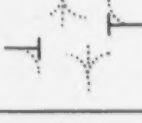
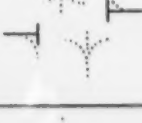
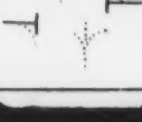
MUNICIPALITY _____

PROVINCE _____

Indicate thusly ☀ if a particular indication is in the flashing mode.

Indicate thusly  P if a particular indication is a JM optically programmed section



Phases/ Traffic Movements	Pedestrian Movements	SIGNAL HEADS FACING SOUTH				Pedestrian Heads N-S Movement	SIGNAL HEADS FACING NORTH	
								
								
								
								
								
								
								

INTERSECTION CONFIGURATION DIVIDED
No separate left turn lane
Opposing left turn allowed

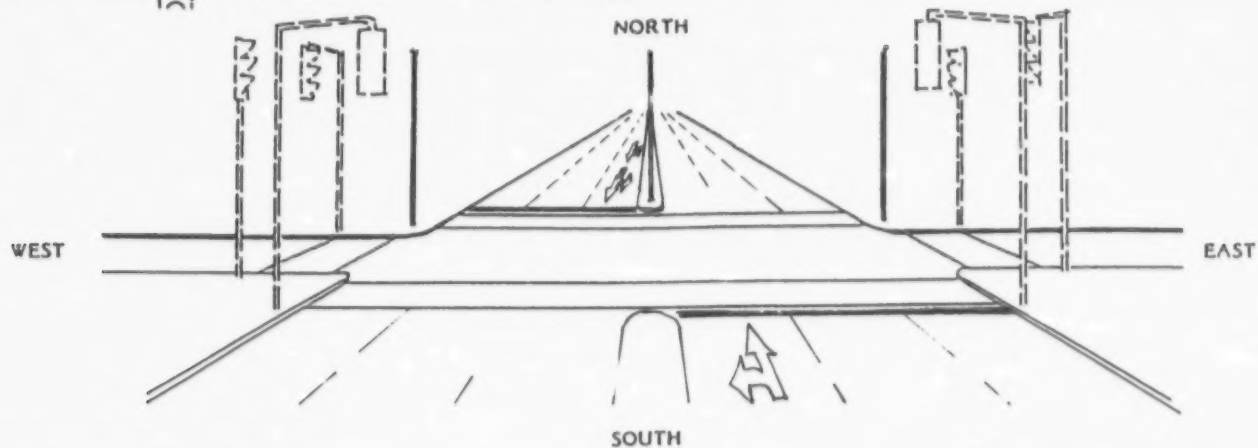
FIGURE **D-2**

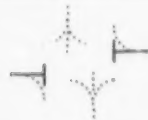
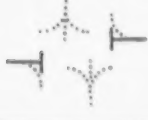
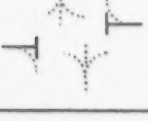
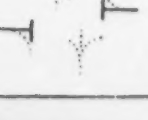
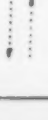
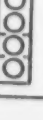
MUNICIPALITY _____

PROVINCE _____

Indicate thusly  if a particular indication is in the flashing mode.

Indicate thusly  if a particular indication is a JM optically programmed section



Phases/ Traffic Movements	Pedestrian Movements	SIGNAL HEADS FACING SOUTH				Pedestrian Heads N-S Movement	SIGNAL HEADS FACING NORTH	
								
								
								
								
								
								
								

INTERSECTION CONFIGURATION DIVIDED
Separate left turn lane designated
No opposing left turn lane
(Opposing left turn prohibited)

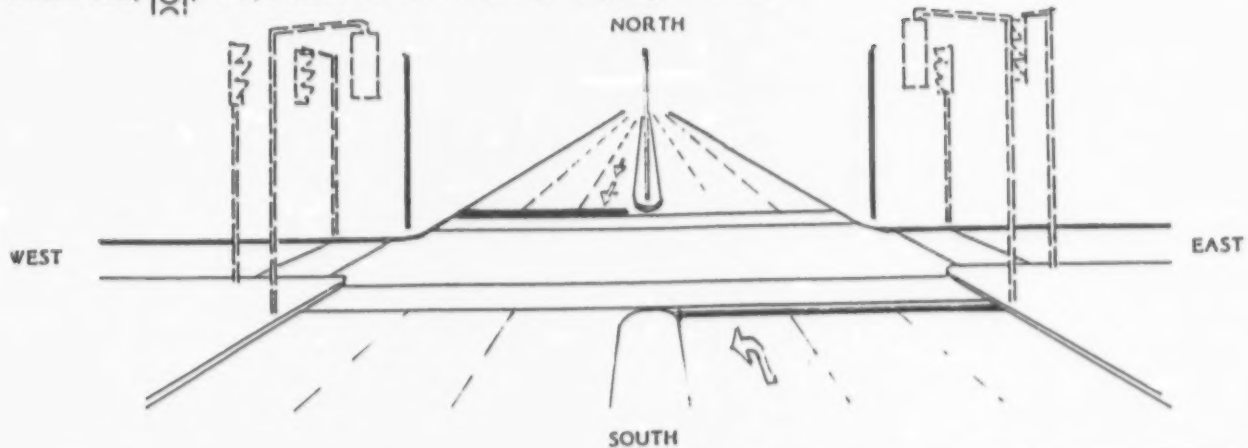
FIGURE **D-3**

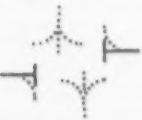
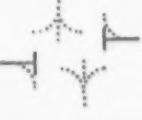
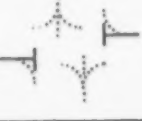
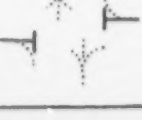
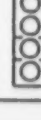
MUNICIPALITY _____

PROVINCE _____

Indicate thusly  if a particular indication is in the flashing mode.

Indicate thusly  P if a particular indication is a JM optically programmed section



Phases/ Traffic Movements	Pedestrian Movements	SIGNAL HEADS FACING SOUTH				Pedestrian Heads N-S Movement	SIGNAL HEADS FACING NORTH	
								
								
								
								
								
								
								

INTERSECTION CONFIGURATION DIVIDED

Left turn lanes designated -
offset from each other

Opposing left turn allowed

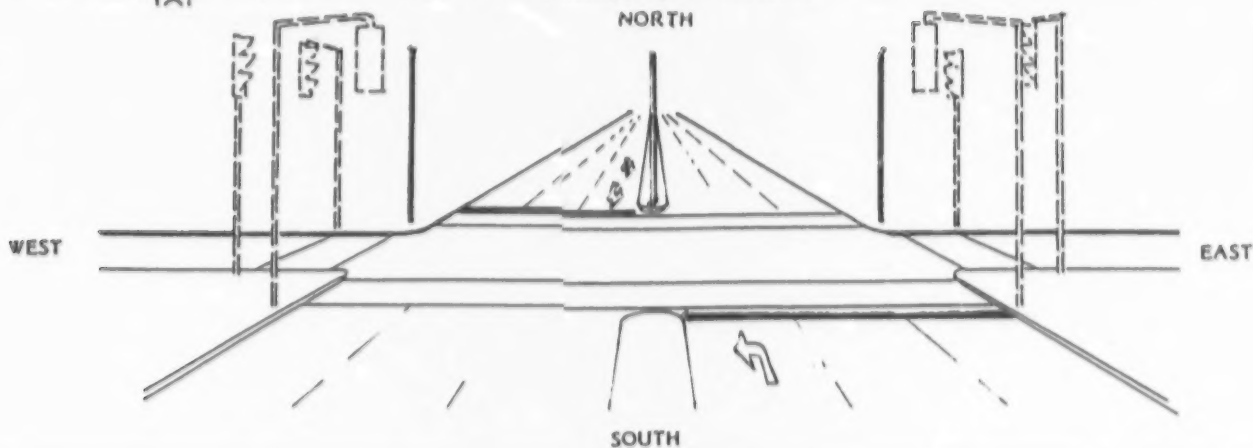
Indicate thusly  if a particular indication is in the flashing mode.

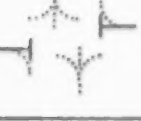
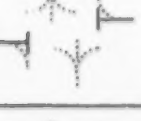
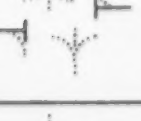
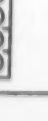
Indicate thusly  if a particular indication is a JM optically programmed section

FIGURE D-4

MUNICIPALITY

PROVINCE



Phases/ Traffic Movements	Pedestrian Movements	SIGNAL HEADS FACING SOUTH				Pedestrian Heads N-S Movement	SIGNAL HEADS FACING NORTH	
								
								
								
								
								
								
								

INTERSECTION CONFIGURATION DIVIDED
Left turn lane encroaching left of centre line
without opposing left turn lane

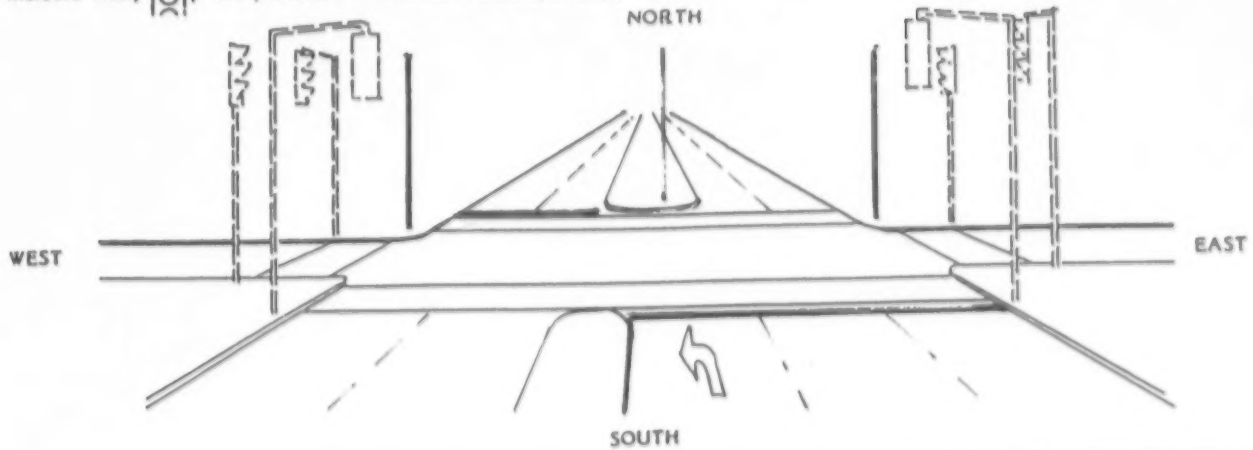
FIGURE D-5

MUNICIPALITY _____

PROVINCE _____

Indicate thusly ☼ if a particular indication is in the flashing mode.

Indicate thusly |⊙|P if a particular indication is a JM optically programmed section



Phases/ Traffic Movements	Pedestrian Movements	SIGNAL HEADS FACING SOUTH				Pedestrian Heads N-S Movement	SIGNAL HEADS FACING NORTH	
		☐	☐	☐	☐		☐	☐

INTERSECTION CONFIGURATION DIVIDED
Opposing left turn lanes
encroaching left of centre line
(partially offset)

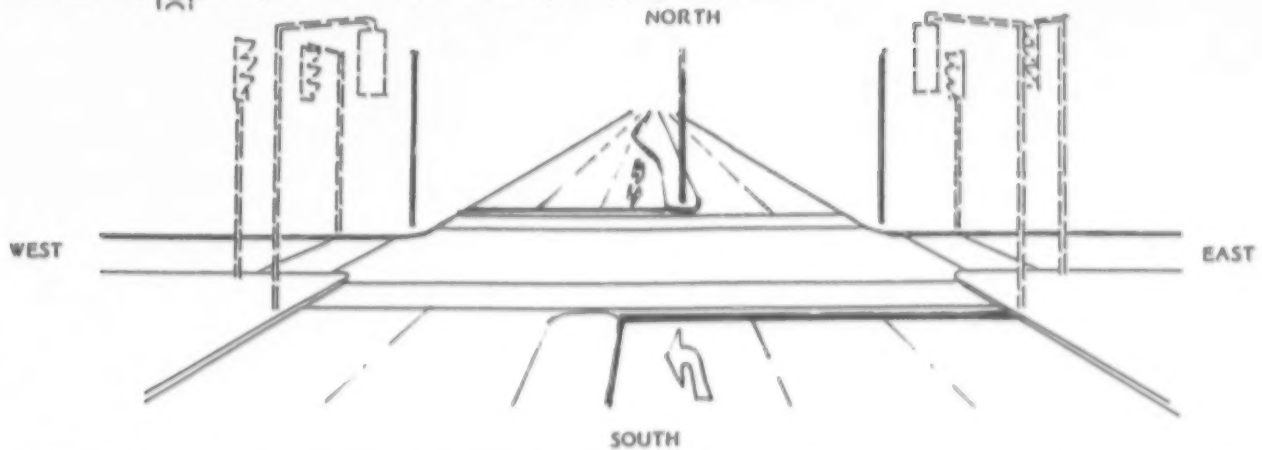
FIGURE **D-6**

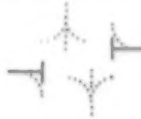
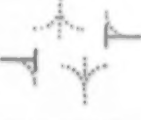
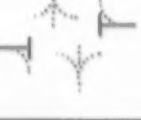
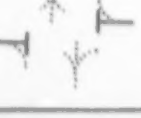
MUNICIPALITY _____

PROVINCE _____

Indicate thusly  if a particular indication is in the flashing mode.

Indicate thusly  if a particular indication is a JM optically programmed section



Phases/ Traffic Movements	Pedestrian Movements	SIGNAL HEADS FACING SOUTH				Pedestrian Heads N-S Movement	SIGNAL HEADS FACING NORTH	
								
								
								
								
								
								
								

INTERSECTION CONFIGURATION DIVIDED
Double (2) left turn lanes
with opposing left turn lane(s)

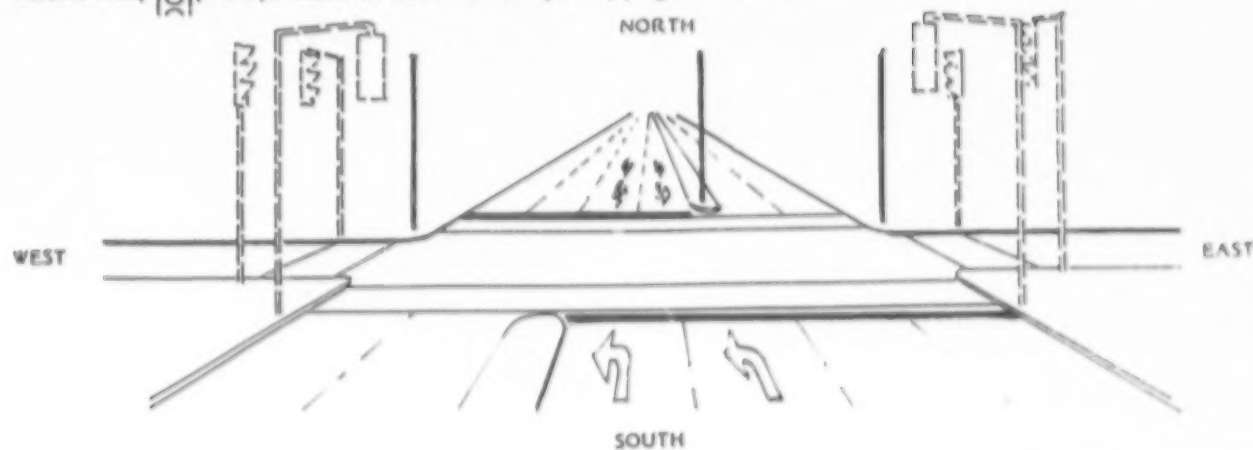
FIGURE D-7

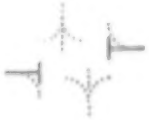
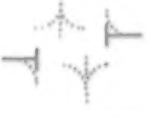
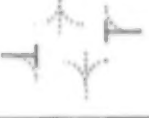
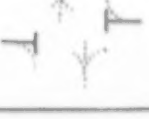
MUNICIPALITY _____

PROVINCE _____

Indicate thusly  if a particular indication is in the flashing mode.

Indicate thusly  if a particular indication is a JM optically programmed section



Phases/ Traffic Movements	Pedestrian Movements	SIGNAL HEADS FACING SOUTH				Pedestrian Heads N-S Movement	SIGNAL HEADS FACING NORTH	
								
								
								
								
								
								
								

INTERSECTION CONFIGURATION DIVIDED
Double (2) left turn lanes
No opposing left turn lanes

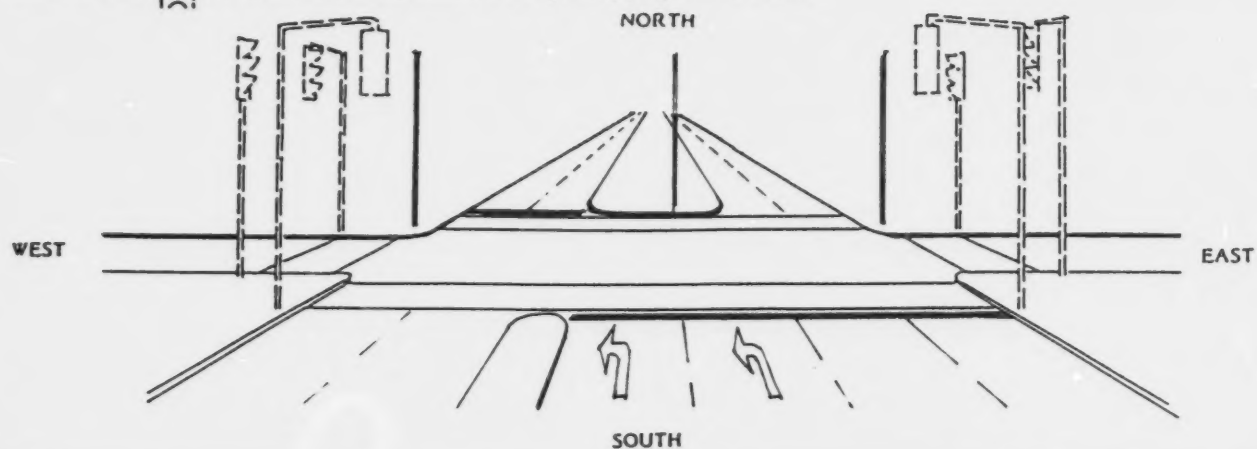
FIGURE **D-8**

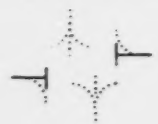
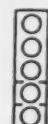
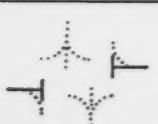
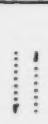
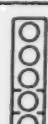
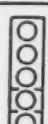
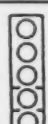
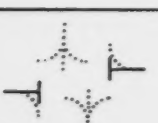
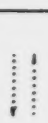
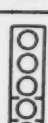
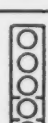
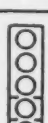
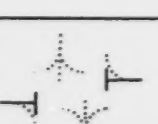
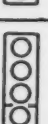
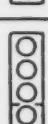
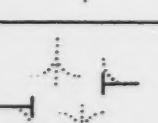
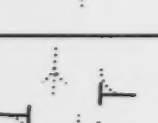
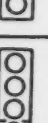
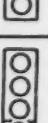
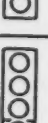
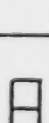
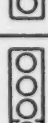
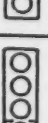
MUNICIPALITY _____

PROVINCE _____

Indicate thusly  if a particular indication is in the flashing mode.

Indicate thusly  if a particular indication is a JM optically programmed section



Phases/ Traffic Movements	Pedestrian Movements	SIGNAL HEADS FACING SOUTH				Pedestrian Heads N-S Movement	SIGNAL HEADS FACING NORTH	
								
								
								
								
								
								
								

INTERSECTION CONFIGURATION with opposing left turn lane

Left turn lanes significantly offset from each other

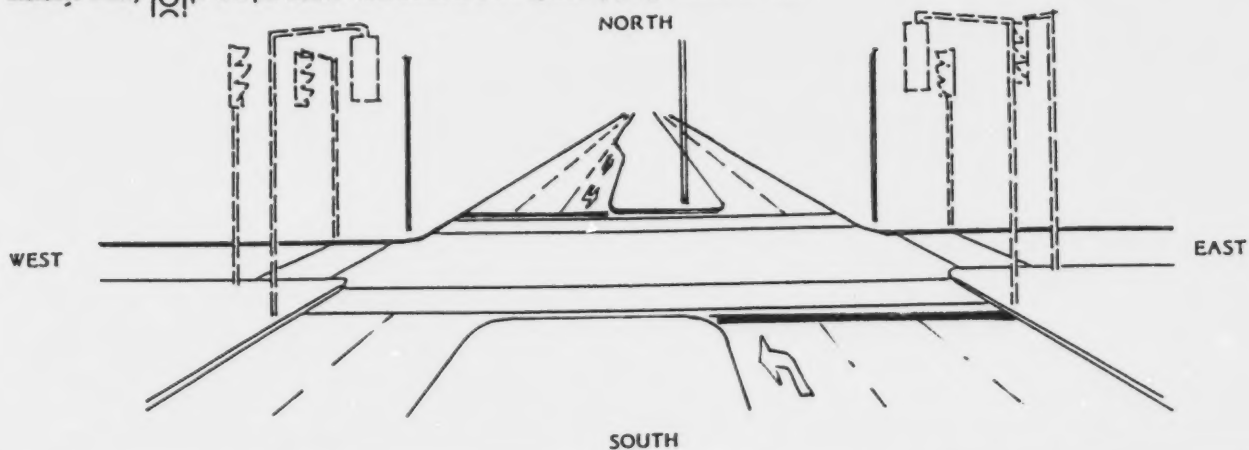
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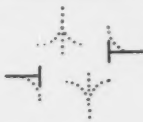
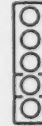
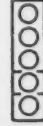
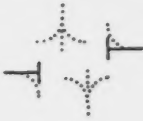
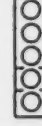
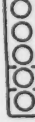
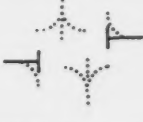
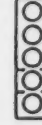
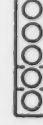
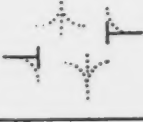
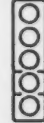
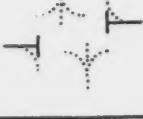
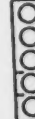
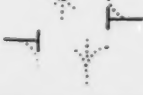
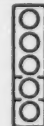
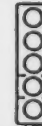
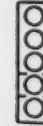
Indicate thusly P if a particular indication is a 3M optically programmed section

FIGURE D(WM)-1

MUNICIPALITY

PROVINCE



Phases/ Traffic Movements	Pedestrian Movements	SIGNAL HEADS FACING SOUTH				Pedestrian Heads N-S Movement	SIGNAL HEADS FACING NORTH	
								
								
								
								
								
								
								

**DIVIDED -
INTERSECTION CONFIGURATION WIDE MEDIAN**
No opposing left turn lane
Left turn lane significantly offset from
opposing through lanes

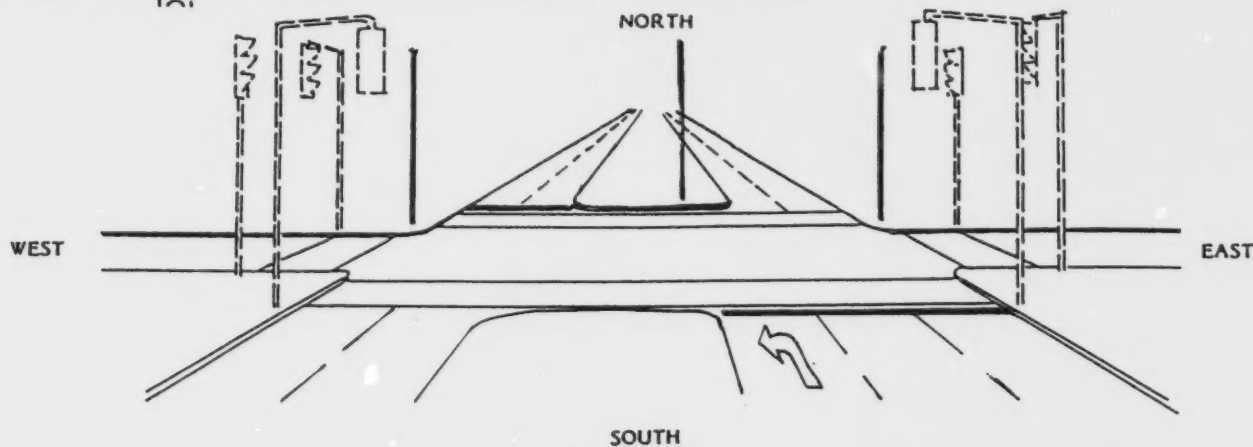
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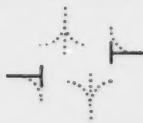
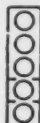
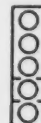
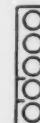
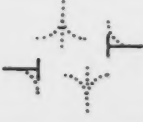
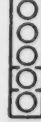
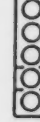
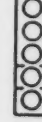
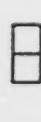
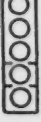
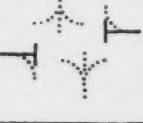
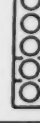
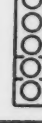
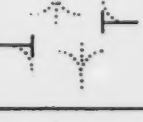
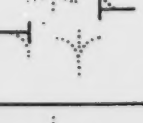
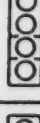
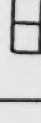
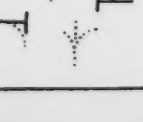
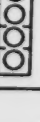
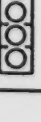
MUNICIPALITY _____

PROVINCE _____

Indicate thusly  if a particular indication is in the flashing mode.

Indicate thusly  if a particular indication is a 3M optically programmed section



Phases/ Traffic Movements	Pedestrian Movements	SIGNAL HEADS FACING SOUTH				Pedestrian Heads N-S Movement	SIGNAL HEADS FACING NORTH	
								
								
								
								
								
								
								

APPENDIX C
TABULATION OF RESPONSES TO THE QUESTIONNAIRE



TABLE 1
BASIS FOR DETERMINING
THE NEED FOR A LEFT-TURN PHASE

(Question 1A)

Province and City or Region	More than Two Left- Turning Vehicles Per Cycle	Highway Capacity Manual	Field Observation	Other
British Columbia				
Burnaby (D)		X	X	
Coquitlam (D)		X		Note 1
Kamloops			X	
Langley		X		Note 2
Maple Ridge (D)		X		Note 3
Matsqui (D)			X	Note 4
Nanaimo		X	X	
Prince George		X		
Saanich (D)		X		Note 5
Surrey (D)			X	Note 6
Trail	X			Note 7
Vancouver	X		X	Note 8
Victoria	X	X	X	
Williams Lake	X			
Alberta				
Calgary	X		X	Note 9
Camrose		X	X	Note 10
Edmonton				Note 11
Fort McMurray			X	Note 12
Lethbridge				Note 13
Medicine Hat			X	Note 14
Red Deer	X		X	
Saskatchewan				
North Battleford		X		
Prince Albert			X	Note 15
Regina	X		X	
Saskatoon	X		X	Note 16
Manitoba				
Brandon		X		Note 17
Winnipeg	X		X	Note 18

(D) - District

TABLE I
(continued)

(Question 1A)

BASIS FOR DETERMINING
THE NEED FOR A LEFT-TURN PHASE

Province and City or Region	More than Two Left- Turning Vehicles Per Cycle	Highway Capacity Manual	Field Observation	Other
Ontario				
Barrie	X			Note 19
Belleville		X		Note 20
Brantford	X	X	X	Note 21
Burlington				Note 22
Chatham	X			
Cornwall	X	X		Note 23
Durham (R.M.)	X		X	Note 24
Guelph	X	X	X	Note 25
Hamilton	X		X	Note 26
Kingston	X		X	
Kirkland Lake				Note 27
London		X	X	
Mississauga			X	
Oakville				Note 28
Orillia	X	X		
Ottawa-Carleton (R.M.)	X		X	Note 29
Peel (R.M.)	X			Note 30
St. Thomas				Note 31
Sarnia	X			
Sault Ste. Marie	X	X		Note 32
Sudbury				Note 33
Thunder Bay			X	Note 34
Toronto (Metro)			X	Note 35
Wallaceburg		X	X	
Waterloo (R.M.)				Note 36
Windsor		X	X	Note 37
Quebec				
Anjou			X	
Hull		X		Note 38
Joliette	X			Note 39
Jonquiere			X	
Laval				Note 40

(R.M.) - Regional Municipality

TABLE 1
(continued)

(Question 1A)

**BASIS FOR DETERMINING
THE NEED FOR A LEFT-TURN PHASE**

Province and City or Region	More than Two Left- Turning Vehicles Per Cycle	Highway Capacity Manual	Field Observation	Other
Quebec (cont'd)				
Montreal			X	Note 41
Quebec		X		Note 42
Rimouski		X	X	
Saint-Hyacinthe			X	
Saint-Laurent		X		
Sherbrooke		X	X	
Thetford Mines			X	
Victoriaville			X	
New Brunswick				
Fredericton		X		
Saint John			X	Note 43
Nova Scotia				
Halifax			X	
Prince Edward Island				
Charlottetown			X	
Newfoundland				
Corner Brook			X	Note 44
St. John's				Note 45
Provincial				
British Columbia	X		X	Note 46
Alberta		X	X	
Manitoba	X		X	
Ontario	X	X	X	Note 47
Quebec		X		Note 48
New Brunswick			X	
Nova Scotia			X	Note 49

NOTES TO TABLE 1

- Note 1 Coquitlam (D) - With consideration of future development.
- Note 2 Langley - The specified lane capacities are often modified, but the Highway Capacity Manual (HCM) approach is usually applied.
- Note 3 Maple Ridge (D) - MUTCD B3.10
- Note 4 Matsqui (D) - RTAC Geometric Design Standards Section D.9.2.
- Note 5 Saanich (D) - Evaluation of critical lane movements.
- Note 6 Surrey (D) - Left-turn movement delaying through movement (reducing capacity); vehicle accidents related to left-turn movements; public complaints.
- Note 7 Trail - Four vehicles turning per cycle
- Note 8 Vancouver - (1) Effect on overall traffic pattern; (2) Accident problem; (3) Delay; (4) Flexibility - cost, signal timing constraints and effect on progression.
- Note 9 Calgary - Number of vehicles requiring more than one cycle to clear intersection.
- Note 10 Camrose - Political Pressure
- Note 11 Edmonton -
- minimum 3 veh/cycle during peaks
- frequent left-turn delays of one cycle or more
- queue of 2 or more vehicles per cycle at start of green
- fewer than 50% of left turns on green
- more than an average of 2 vehicles per cycle on amber and all-red, thereby impeding cross-street traffic
- time is available from opposing movements or the cross-street
- Note 12 Fort McMurray - Edmonton policies that have been adopted by the City of Fort McMurray.
- Note 13 Lethbridge - Left turns exceed 10% of the through volume.
- Note 14 Medicine Hat - RTAC Geometric Design Standards, and also political influences.
- Note 15 Prince Albert - Intersection delay study (Manual of Traffic Engineering Studies).

NOTES TO TABLE 1

- Note 16 Saskatoon - Where the loss of green time for the left-turn phase would not cause over-saturation on through movements.
- Note 17 Brandon - Left-turn delay study.
- Note 18 Winnipeg - At times, an unusually high number of collisions between a left-turning vehicle and a straight through vehicle is a basis for determining the need.
- Note 19 Barrie - The specific operation at certain intersections where the left-turn volume is sufficient at peak periods to adversely affect the capacity of the intersection or roadway adjoining the intersection.
- Note 20 Belleville - Council (political) direction.
- Note 21 Brantford - All points are taken into consideration
- Note 22 Burlington - MTC Traffic Control Signal Timing and Capacity Analysis Manual for Signalized Intersections.
- Note 23 Cornwall - More than two left-turning vehicles per cycle for at least 8-15 minute periods and HCM less 2 left-turning vehicles per cycle for at least 1 of these 15 minute periods.
- Note 24 Durham (R.M.) - Left-turn head-on collisions, queueing problems between short signalized blocks.
- Note 25 Guelph - All of the methods have been combined to best evaluate the situation.
- Note 26 Hamilton - Australian Road Research Board left-turn equivalence method - see A.R.R.B. Report No. 79.
- Note 27 Kirkland Lake - MTC Traffic Control Signal Timing and Capacity Analysis Manual for Signalized Intersections.
- Note 28 Oakville - On average, where left-turn movement equals or exceeds 10% of volume.
- Note 29 Ottawa-Carleton (R.M.) - Left-turn phases are normally installed only if the following three conditions are satisfied: 1) average demand over heaviest hour exceeds two left-turning vehicles per signal cycle, 2) field surveys show that the probability of clearance for left-turning vehicles over the heaviest hour is less than 50% and 3) sufficient intersection capacity exists to enable all traffic movements to operate at design level of service after the left-turn phase has been installed.

NOTES TO TABLE 1

- Note 30 Peel (R.M.) - Left-turn queueing study is carried out, if initial volume count indicates more than two left turns per cycle.
- Note 31 St. Thomas - MTC Traffic Control Signal Timing and Capacity Analysis Manual as guide to calculate need for left turns.
- Note 32 Sault Ste. Marie - Compliance with the HCM formula and more than 2 vehicles per cycle turning left and/or no less than 100 left turns per hour and number of lanes permit separate left turn in the case of opposite left turns.
- Note 33 Sudbury - Critical lane volume of left turns plus opposing through volumes is greater than 1200 vph.
- Note 34 Thunder Bay - If a need is shown where left-turn vehicles back up out of designated left-turn lanes, or if a problem other than the pm peak.
- Note 35 Toronto (Metro) - Traffic Control Centre guidelines
- Note 36 Waterloo (R.M.) - Combination of cited methods and SSTOP program output re: degrees of saturation on links utilizing left-turn phase.
- Note 37 Windsor - Field observation or public demand.
- Note 38 Hull - Hewton's Signal Timing Procedure.
- Note 39 Joliette - When opposing traffic exists.
- Note 40 Laval - Quebec Signalization Manual or the Canadian geometric design standards
- Note 41 Montreal - Number of left-turning vehicles and the availability of gaps in the opposing traffic
- Note 42 Quebec - Quebec Manual of General Instructions (Signals Section) on Traffic Control Devices.
- Note 43 Saint John - If field observation indicates a problem, traffic counts are taken (7-11 a.m. & 2-6 p.m.) to determine percentage left-turns (generally 10% of approaching traffic warrants phase).
- Note 44 Corner Brook - Recommendations from the Traffic Commission, which are followed up by vehicle counts.

NOTES TO TABLE 1

- Note 45 St. John's - The number of vehicles making a left turn from any one of a pair of opposed approaches exceeds 20% of the through volume in the heavy direction, and political pressure.
- Note 46 British Columbia - T.R.B. Circular 212, Toronto Capacity Guide, Edmonton Saturation Flow Manual. Peak hour volumes used for analysis.
- Note 47 Ontario - Combination of all three
- Note 48 Quebec (Prov.) - Equal levels of service for left turn and through traffic.
- Note 49 Nova Scotia - Actuated signals, with skip phase capability.

TABLE 2
METHOD USED TO DETERMINE LEFT-TURN PHASE TIME

(Question 1B)

Province and City or Region	Responses
British Columbia	
Burnaby (D)	Calculation of equivalent hourly volume, phase time table B4.11 in the MUTCDC Check of phase time capacity using G/C ratios and intersection capacity nomograph
Coquitlam (D)	(1) Experimentation in field after installation and/or (2) W.E. Ewens Method
Kamloops	Mostly field observation. Minimum time when called up is 4-5 sec with 3-sec extensions for each crossing of the loop
Langley	Time is usually based on required G/C using expected volume splits and capacities (generally conforming with HCM)
Matsqui (D)	Volume Ratio
Nanaimo	Field observation
Prince George	Charts G.6 from RTAC Standards
Saanich (D)	Highway Capacity Manual
Surrey (D)	Minimum 5 seconds with 3-second extensions to maximum
Trail	Experience
Vancouver	Time required to service left-turn demand versus the green time available. A minimum of 6 seconds green time is used for left-turn arrows
Victoria	If left-turn volume is less than 250 6 second + clearance is used. If greater than 250, 6 seconds to a maximum of 15 seconds + clearance is used.
Alberta	
Calgary	Webster Method
Camrose	Calculations based on vehicle counts to maximize intersection capacity - then fine tuned in field

(D) - District

TABLE 2
(continued)

(Question 1E)

METHOD USED TO DETERMINE LEFT-TURN PHASE TIME

Province and City or Region	Responses
Alberta (cont'd)	
Edmonton	SINTRAL (computer program)
Fort McMurray	Basic lane capacity and volume flow analysis to clear left-turning demand that cannot penetrate available gaps in opposing flow
Lethbridge	Vehicle counts
Medicine Hat	All traffic lights are actuated except two installations. Field observation used to time the lengths
Red Deer	((Design period left-turn vehicular approach volume) - ((1.5 to 2) x (# cycles during design period))) ÷ (left-turn vehicular saturation flow rate)
Saskatchewan	
Prince Albert	1. A minimum timing. 2. Length of left-turn bay. 3. Time of day (volume). 4. Coordination of a system of signals
Regina	A time is selected based on the number of left-turn vehicles and the number of cycles/hr. Field observation is then used to determine whether the selected time is adequate
Saskatoon	Minimum of 6 seconds, (volume/saturation flow) x cycle length
Manitoba	
Winnipeg	Headway timing method, assuming 2.5 second average headway. Amount of time left after assigning timings to major movements. Minimum "Green-arrow" interval length = 6 seconds for fixed time controllers and 3 seconds for actuated controllers.
Ontario	
Barrie	Basic timing found adequate from field observation which has also been compared with other municipalities and which does not adversely affect cycle length. Usually 8-10 secs.
Belleville	Loops or pretimed controller by percentage of cycle time

TABLE 2
(continued)

(Question 1B)

METHOD USED TO DETERMINE LEFT-TURN PHASE TIME

Province and City or Region	Responses
Ontario (cont'd)	
Brantford	Minimum phase time of 7 seconds plus 2 seconds of clearance time
Burlington	MTC Manual*
Chatham	MTC Manual*
Cornwall	Variation on MTC Manual* Shortcut Method of signal timing: subtract 2 veh/cycle from total equiv. L.T. volume, add total equiv. opposing vol. Excess of this value over 1200 X G/C used for design at LOS, E.
Durham (R.M.)	MTC Manual*
Guelph	Ewen's Method
Hamilton	ARRB equivalence method; City of Hamilton saturation flows (from field measurements of left turns); short-cut method derived from E. Ewens
Kingston	10-12 seconds. Longer if field observation indicates the need
Kirkland Lake	$G \text{ in seconds} = \text{cycle length} \times (\text{demand volume} - \text{greater of Chart 31 (MTC Manual*)}) \div 1500 \text{ vphg}$
London	"A Method for Signal Timing, Capacity Calculations & Level of Service Determination at Signalized Intersections" by W.E. Ewens
Oakville	Usually by field observation since almost all intersections are actuated
Orillia	Table B.3, MUTCD and observation of traffic conditions at the intersection
Ottawa-Carleton (R.M.)	Sufficient time is provided to service left-turn demand at level of service E based on the Ewens Probability charts. It is normally assumed that two left-turns per the signal cycle are serviced during clearance intervals. If left-turning traffic forms a major movement at the intersection, its level of service will be equalized with other major movements.

(R.M.) - Regional Municipality

* - MTC Traffic Control Signal Timing and Capacity Analysis Manual

TABLE 2
(continued)

(Question 1B)

METHOD USED TO DETERMINE LEFT-TURN PHASE TIME

Province and City or Region	Responses
Ontario (cont'd)	
Peel (R.M.)	Adv. Green = $1.9N + 4.2$ where N = vehicles arriving per cycle - 2
Sarnia	MTC Manual* chart (timing capacity/length of storage lanes) minimum of 8 sec. green
Sault Ste. Marie	As per notes (a), (b) & (c), Table 6c in "Traffic Signals" by Tom Hewton but using $t = 5 + 1.8x$ rather than $t = 10 + 1.8x$
Sudbury	Average vehicle demand per cycle - 2 vehicles per clearance and result used with vehicle headways to arrive at the signal timing
Thunder Bay	Minimum of 7 seconds or the MTC Manual* for determining adequate timing
Toronto (Metro)	a) Time available within existing cycle b) Volume/capacity analysis
Wallaceburg	HCM, Field observation
Waterloo (R.M.)	Field observation of conditions. SSTOP output.
Windsor	Proportionate to phase volumes
Quebec	
Anjou	Each intersecetion is different. Recommendations of traffic committee considered.
Joliette	The number of left-turn vehicles vs. the number of opposing through vehicles
Jonquiere	Number of vehicles per cycle
Laval	Highway Capacity Manual method and "Traffic Engineering Theory and Practice"

(R.M.) - Regional Municipality

* - MTC Traffic Control Signal Timing and Capacity Analysis Manual

TABLE 2
(continued)

(Question 1B)

METHOD USED TO DETERMINE LEFT-TURN PHASE TIME

Province and City or Region	Responses
Quebec (cont'd)	
Montreal	(Number of left turns per cycle -2) x 2.5 sec. Time is also adjusted depending on opposing traffic volumes at each site
Quebec	In accordance with the procedures in the Quebec Manual of General Instructions on Traffic Control Devices (Signals Section).
Rimouski	Initial minimum time plus a variable extension up to a maximum. All dependent on an intersection traffic study.
Saint-Hyacinthe	10% of cycle time
Saint-Laurent	The number of vehicles in percent of total volume for the cycle length
Sherbrooke	Use volumes for the peak period in which the turning movement is identified, multiplied by the appropriate factor = volume equivalent.
Thetford Mines	The number of vehicles which turn left during the clearance interval to maintain satisfactory traffic flow
Victoriaville	Field observation
New Brunswick	
Saint John	Using traffic counts, an initial time is selected and adjusted to fit the demand for left turns
Nova Scotia	
Halifax	Approximately the ratio of the vehicular demand for left-turn feature to be installed (usually a little less for this component) vs. heaviest used approach lane on same roadway vs. heaviest used lane on intersecting street
Prince Edward Island	
Charlottetown	Field observation

TABLE 2
(continued)

(Question 1B)

METHOD USED TO DETERMINE LEFT-TURN PHASE TIME

Province and City or Region	Responses
Newfoundland	
Corner Brook	Method outlined in Canadian MUTCD
St. John's	Traffic counts are conducted to determine left-turn volume. Then MTC's method of traffic control signal timing is used to determine phase time
Provincial	
British Columbia	Peak hour count converted to through units, applied to Greenshield's calculation, TRB Circular 212, engineering judgment. Since majority of signals are fully actuated, timings are not as critical as for fixed time operation
Alberta	Headway method
Manitoba	The total cycle length, volume of left turns and the number of commercial vehicles making left turns and in some cases the amount of left-turn storage space available
Ontario	MTC Manual*
Quebec	"Failure Rate Method" ratio of V_L/V_C where V_L = volume of left turning vehicles and V_C = total critical volume for the intersection.
New Brunswick	Time to clear left turns most of the cycles
Nova Scotia	Volume of left-turning traffic - field observations - Actuated signals with skip phase capability

* - MTC Traffic Control Signal Timing and Capacity Analysis Manual

TABLE 3 **(Question 1C)**
PORTION OF "ADVANCED GREEN" LEFT-TURN PHASE
DEDICATED TO A CLEARANCE INTERVAL

Province and City or Region	Clearance Interval Used?	Length (Sec)	Clearance Interval Time Determined From
British Columbia			
Burnaby (D)	Yes	Same as Amber Interval	Clearance interval table B3.15 in MUTCDC
Coquitlam (D)	Yes	3.5-4.5	Consideration given to roadway geometry (angles of intersections, no. of lanes)
Kamloops	Yes	3	Using 3 sec as always used. No need for change - no problems
Langley	Yes	3-4	Intersection geometrics (similar to consideration for through movement clearance interval)
Maple Ridge (D)	Yes	3.2	HCM, MUTCDC, field observation
Nanaimo	Yes	4 ±	Field observation
Prince George	Yes	3 to 5	Speed of the approach and the width of intersection
Saanich (D)	Yes	-	Table 3.15 - MUTCDC
Surrey (D)	Yes	MUTCDC Table 3.15	Street width, approach speed, intersection characteristics
Trail	Yes	7	Experience
Vancouver	Yes	4	4 sec unless there is a large crossing distance
Victoria	Yes	3	Time required to clear the centre of the last opposing lane
Williams Lake	No	-	-

(D) - District

TABLE 3
(continued)

(Question 1C)

**PORTION OF "ADVANCED GREEN" LEFT-TURN PHASE
DEDICATED TO A CLEARANCE INTERVAL**

Province and City or Region	Clearance Interval Used?	Length (Sec)	Clearance Interval Time Determined From
Alberta			
Calgary	Yes	2-3	Using a minimum of 2 secs; longer if field observations indicate a need
Camrose	Yes	2	Calculations based on intersection width, speed limit. Time checked in field
Edmonton	Yes	4 Max.	Using a maximum time of 5 sec. If more, drivers tend to make extensive use of clearance interval
Fort McMurray	Yes	3 Amber 2 All-Red	Size of intersection and an intergreen analysis
Lethbridge	Yes	2	Observation
Medicine Hat	Yes	Varies	Road width and field observation
Red Deer	Yes	-	Design speed & associated accel/decel. rate, reaction/perception time, clearance path length, etc.
Saskatchewan			
North Battleford	Yes	1.5	Fixed time timing dial
Prince Albert	Yes	2	Standard policy
Regina	Yes	1.5 All-Red	Using 1.5 sec. clearance as a standard
Saskatoon	Yes	0-3	Field observation
Manitoba			
Winnipeg	Yes	4	Using time as per standard amber clearance interval

TABLE 3
(continued)

(Question 1C)

**PORTION OF "ADVANCED GREEN" LEFT-TURN PHASE
DEDICATED TO A CLEARANCE INTERVAL**

Province and City or Region	Clearance Interval Used?	Length (Sec)	Clearance Interval Time Determined From
Ontario			
Barrie	Yes	approx. 2	Standard practice, modelled after Toronto, found satisfactory in Barrie
Belleville	Yes	2	City policy of 2 sec.
Brantford	Yes	2	MUTCDC
Burlington	Yes	2	Using 2 sec throughout city
Chatham	Yes	2	Using a maximum of 2 seconds
Cornwall	Yes	1.5-2.5	Using Ontario MUTCD Min. 1.5 sec to max 2.5 sec solid green
Durham (R.M.)	Yes	2	Using 2 sec unless intersection width requires more time
Guelph	Yes	2	Using consistent 2 sec. at all intersections having advanced greens
Hamilton	Yes	2 (sometimes more than 2)	Using 2.0 sec $\pm$, unless site considerations dictate otherwise. As per Ontario MUTCD
Kingston	No	-	
Kirkland Lake	Yes	2	Standard practice
London	Yes	1.5-2.5	Local operating requirements
Mississauga	Yes	1	-
Oakville	Yes	2	Increasing from 2 sec for wider intersections

(R.M.) - Regional Municipality

TABLE 3
(continued)

(Question 1C)

PORTION OF "ADVANCED GREEN" LEFT-TURN PHASE
DEDICATED TO A CLEARANCE INTERVAL

Province and City or Region	Clearance Interval Used?	Length (Sec)	Clearance Interval Time Determined From
Ontario (cont'd)			
Orillia	Yes	-	Using 1-2% of cycle length (ie. 80 sec cycle = 1.6 sec or 2%), MUTCD, min 5 sec subject to change at all-red installations
Ottawa-Carleton (R.M.)	Yes	1.5-2.5	Using a green clearance interval varying from 1.5 to 2.5 sec depending on intersection width
Peel (R.M.)	Yes	2.0-2.5	Field observation - time required to basically clear the intersection
St. Thomas	Yes	2	Recommendations in the St. Thomas Traffic Operations Study (1975)
Sarnia	Yes	approx 1	MTC standards for clearance intervals. In new installations
Sault Ste. Marie	Yes	1.6-2.4	Using $\frac{\text{intersection width (m)}}{\text{speed (km/h)} \times 0.28}$ Similar to "all-red"
Sudbury	Yes	-	Using travel distance to clear crosswalks
Thunder Bay	Yes	2	-
Toronto (Metro)	Yes	2-3	Using 2 seconds, plus established practice based on experience, other factors include geometry (intersection size), speed limit, type of vehicles turning plus visibility

(R.M.) - Regional Municipality

TABLE 3
(continued)

(Question 1C)

PORTION OF "ADVANCED GREEN" LEFT-TURN PHASE
DEDICATED TO A CLEARANCE INTERVAL

Province and City or Region	Clearance Interval Used?	Length (Sec)	Clearance Interval Time Determined From
Ontario (cont'd)			
Waterloo (R.M.)	Yes	2	Min. interval timing constraints established through T-200 Traffic Control Software
Windsor	Yes	1-1.5	
Quebec			
Anjou	No	-	-
Hull	Yes	4-5	Quebec provincial standard
Joliette	No	-	-
Jonquiere	No	-	-
Laval	Yes	1-3	% left turns with regard to opposing through traffic and operating speed
Montreal	Yes	3-5	One-half the width of the intersection
Quebec	Yes	3-6	Width of the intersection
Rimouski	Yes	6	The time required to clear the intersection
Saint-Hyacinthe	No	-	-
Saint-Laurent	Yes	4	-
Sherbrooke	Yes	3-4	Width of roadway and approach speed

(R.M.) - Regional Municipality

TABLE 3
(continued)

(Question 1C)

**PORTION OF "ADVANCED GREEN" LEFT-TURN PHASE
DEDICATED TO A CLEARANCE INTERVAL**

Province and City or Region	Clearance Interval Used?	Length (Sec)	Clearance Interval Time Determined From
Quebec (cont'd)			
Thetford Mines	No	-	-
Victoriaville	Yes	5	Field observations
New Brunswick			
Fredericton	No	-	-
Saint John	Yes	3	Left-turn phase is followed by green while opposing approach remains red for 3 seconds. Amber or amber plus red is not used
Nova Scotia			
Halifax	Yes	3.0-4.8 usually 3.5-3.6	Judgment plus Traffic Engineering Handbook (where distance used for the clearance interval formula is from the stop bar to the farthest point where left-turning traffic would clear next scheduled opposing flow)
Prince Edward Island			
Charlottetown	No	-	-
Newfoundland			
Corner Brook	Yes		Table B.3.15, Canadian MUTCD
St. John's	Yes	varies	Depends on length of clearance path - Canadian MUTCD and/or MTC method of Traffic Control Signal Timing

TABLE 3
(continued)

(Question 1C)

**PORTION OF "ADVANCED GREEN" LEFT-TURN PHASE
DEDICATED TO A CLEARANCE INTERVAL**

Province and City or Region	Clearance Interval Used?	Length (Sec)	Clearance Interval Time Determined From
Provincial			
British Columbia	Yes	3.5-4.0	Width of intersection, ITE calculation used as a guideline
Alberta	Yes	4	Canadian MUTCD
Manitoba	Yes	3-4	Standard clearance time based on operating speeds
Ontario	Yes	-	MTC Manual
Quebec	Yes	4-5	Approach speed and size of intersection
New Brunswick	No	-	-
Nova Scotia	Yes	4	Normal amber clearance times

TABLE 4 (Question 1D)

TYPE OF LEFT-TURN PHASING USED
AND GUIDELINES APPLIED IN THE SELECTION OF THE TYPE OF PHASING

Province and City or Region	Advanced Green	Leading Simult. L.T.	Extend. Green (X = not used)	Lagging Simult. L.T.	Excl/ Prot. L.T.	Sep/ Prot. L.T.	Notes on Guidelines (See Attached)
British Columbia							
Burnaby (D)	used	X	X	X	used	used	Note 1
Coquitlam (D)	X	X	X	X	used	X	Note 2
Kamloops	used	X	X	X	used	used	Note 3
Langley	used	used	used	used	used	X	Note 4
Maple Ridge (D)	used	X	used	X	X	X	Note 5
Matsqui (D)	X	X	X	X	used	X	Note 6
Nanaimo	-	-	-	-	-	-	Note 7
Prince George	used	used	X	X	X	used	Note 8
Saanich (D)	used	used	X	X	used	X	Note 9
Surrey (D)	used	used	X	X	X	X	Note 10
Trail	-	X	-	-	-	-	Note 11
Vancouver	used	X	used	used	used	X	Note 12
Victoria	used	-	used	X	used	used	
Alberta							
Calgary	used	used	used	used	used	used	Note 13
Camrose	used	X	X	X	X	X	Note 14
Edmonton	used	-	used	-	used	used	Note 15
Fort McMurray	used	X	X	X	X	X	Note 16
Lethbridge	used	used	X	X	used	used	Note 17
Medicine Hat	used	used	X	X	used	used	Note 18
Red Deer	-	-	-	-	-	-	Note 19

(D) - District

TABLE 4
(continued)
(Question 1D)

TYPE OF LEFT-TURN PHASING USED
AND GUIDELINES APPLIED IN THE SELECTION OF THE TYPE OF PHASING

Province and City or Region	Advanced Green	Leading Simult. L.T.	Extend. Green (X = not used)	Lagging Simult. L.T.	Excl/ Prot. L.T.	Sep/ Prot. L.T.	Notes on Guidelines (See Attached)
Saskatchewan							
North Battleford	-	-	-	-	-	-	Note 20
Prince Albert	used	used	X	X	X	X	Note 21
Regina	used	used	X	X	X	used	Note 22
Saskatoon	used	used	used	X	used	used	Note 23
Manitoba							
Winnipeg	used	used	used	used	used	used	Note 24
Ontario							
Barrie	used	X	X	X	used	used	Note 25
Belleville	used	X	X	X	used	X	Note 26
Brantford	used	X	X	X	used	X	Note 27
Burlington	used	used	X	X	-	X	Note 28
Chatham	used	-	-	-	used	-	Note 29
Cornwall	used	X	used	X	X	X	Note 30
Durham (R.M.)	used	used	used	X	X	X	Note 31
Guelph	used	X	used	X	used	X	Note 32
Hamilton	used	X	X	X	used	used	Note 33
Kingston	-	used	X	X	X	used	Note 34
Kirkland Lake	used	used	X	X	X	X	Note 35
London	-	-	-	-	-	-	Note 36
Mississauga	used	used	X	X	used	used	Note 37

(R.M.) - Regional Municipality

TABLE 4
(continued)
(Question 1D)

TYPE OF LEFT-TURN PHASING USED
AND GUIDELINES APPLIED IN THE SELECTION OF THE TYPE OF PHASING

Province and City or Region	Advanced Green	Leading Simult. L.T.	Extend. Green (X = not used)	Lagging Simult. L.T.	Excl/ Prot. L.T.	Sep/ Prot. L.T.	Notes on Guidelines (See Attached)
Ontario (cont'd)							
Oakville	used	used	X	X	X	X	Note 38
Orillia	used	X	X	X	X	X	Note 39
Ottawa-Carleton (R.M.)	used	used	used	used	used	used	Note 40
Peel (R.M.)	used	used	X	X	X	used	Note 41
St. Thomas	used	-	-	-	-	-	Note 42
Sarnia	used	X	X	X	X	X	Note 43
Sault Ste. Marie	used	used	used	X	X	X	Note 44
Sudbury	used	used	used	X	used	used	Note 45
Thunder Bay	used	X	X	X	X	X	Note 46
Toronto (Metro)	used	used	X	X	used	used	Note 47
Waterloo (R.M.)	used	X	X	X	used	X	Note 48
Windsor	used	used	-	-	-	X	
Quebec							
Anjou	-	-	-	used	-	-	Note 49
Hull	-	-	-	-	-	-	Note 50
Joliette	used	used	X	X	X	X	Note 51
Jonquiere	used	used	-	-	-	-	Note 52
Laval	used	used	X	X	used	used	Note 53
Montreal	used	used	used	used	used	X	Note 54
Quebec	used	X	X	X	X	used	Note 55
Rimouski	-	-	-	-	-	-	Note 56
Saint-Hyacinthe	used	X	X	X	used	X	Note 57

TABLE 4
(continued)
(Question 1D)

TYPE OF LEFT-TURN PHASING USED
AND GUIDELINES APPLIED IN THE SELECTION OF THE TYPE OF PHASING

Province and City or Region	Advanced Green	Leading Simult. L.T.	Extend. Green (X = not used)	Lagging Simult. L.T.	Excl/ Prot. L.T.	Sep/ Prot. L.T.	Notes on Guidelines (See Attached)
Quebec (cont'd)							
Saint-Laurent	used	used	used	used	used	used	Note 58
Sherbrooke	used	used	used	used	used	used	Note 59
Thetford Mines	used	used	used	-	-	-	Note 60
Victoriaville	used	-	used	-	-	-	Note 61
New Brunswick							
Fredericton	-	-	-	-	-	-	Note 62
Saint John	used	X	X	X	X	X	Note 63
Nova Scotia							
Halifax	used	X	X	used	used	used	Note 64
Prince Edward Island							
No responses							
Newfoundland							
Corner Brook	used	used	X	X	used	X	Note 65
St. John's	used	used	X	X	used	X	Note 66

TABLE 4
(continued)

TYPE OF LEFT-TURN PHASING USED

[illegible]

NOTES TO TABLE 4

(Question 1D)

Note 1
Burnaby (D)

Advanced Green: used where only one approach has high left-turn volumes and the following permissive interval allows enough gaps for additional left turns to be made safely.

Exclusive/Protected Left Turn: used on high volume multi-lane roadways with left-turn storage protected by raised channelization.

Separate/Protected Left Turn: used on high-volume roadways where left-turn volume exceeds the storage capacity of the left-turn lane or higher capacity can be achieved using this configuration.

Note 2
Coquitlam (D)

Exclusive/Protected Left Turn: used at all intersections. Left-turn phases are actuated, therefore the presence of a left-turn bay is the major criterion once the warrant for the phase has been met.

Present policy has sacrificed some degree of capacity for the sake of safety. However this policy is under review as volumes are increasing.

Note 3
Kamloops

Most of the signals existing in Kamloops which employ separate left-turn phases were installed a long time ago by the Ministry of Highways. The guidelines they used are not known, although believed to be from the T&T Engineering Handbook. All of the most recently installed signals are actuated left-turn phases with a minimum time of approximately 4 seconds and extensions of approximately 3 seconds.

Note 4
Langley

Advanced Green: preferred condition when no left-turn phase provided in opposing direction.

Leading Simultaneous Left Turn: preferred condition when opposing left-turn phases provided.

Extended Green: used only where it is more conducive to signal progression than the advanced green.

Lagging Simultaneous Left Turn: used only where it is more conducive to signal progression than leading simultaneous left turn.

Exclusive/Protected Left Turn: used only on high-speed roads or where very high through volumes, i.e. only used where it is undesirable to provide permissive left turns.

NOTES TO TABLE 4

(Question 1D)

Note 5
Maple Ridge (D)

Separate/Protected Left Turn: generally not used. Might be applied on highly unbalanced intersections (with actuated controllers, this condition can occur when traffic is light from one direction).

Advanced Green: with activated signals, only set minimum and maximum time.

Extended Green: activated.

Note 6
Matsqui

Exclusive/Protected Left Turn: If warranted by volume and accident statistics. All installations utilize fully actuated controllers.

Note 7
Nanaimo

On basis of advice from consulting services.

Note 8
Prince George

Advanced Green: Central median exists, volume of left-turn vehicles greater than 100 vph on one approach

Leading Simultaneous Left Turn: left-turn volume on both approaches greater than 100 vph

Separate/Protected Left Turn: prevailing traffic on one approach only.

Note 9
Saanich (D)

Advanced Green, Leading Simultaneous Left Turn and Exclusive/Protected Left Turn: Evaluation of Critical Lane Movements.

Note 10
Surrey (D)

Advanced Green & Leading Simultaneous Left Turn: left-turn vehicle loop detectors placed in left-turn bays approximately 3 car lengths back of stop bar. Controller will select single or dual left-turn phase as actuated by traffic. If two or less vehicles in left-turn queue controller will activate through phase only and left turns will be made through gaps in opposing traffic or on amber phase.

Exclusive/Protected Left Turn: Not used at municipal traffic signal installations. Used at some provincial signals within this municipality.

NOTES TO TABLE 4

(Question 1D)

Note 11
Vancouver

Advanced Green: One direction has a heavy left-turn demand. Opposing left turns are permitted;

Extended Green: Only used where the opposing left-turn is prohibited;

Lagging Simultaneous Left Turn: Opposing left-turn demand is similar and there are no medians to mount a separate left-turn signal head;

Exclusive/Protected Left-Turn: 8 phase fully actuated signals.

Note 12
Victoria

Advanced Green: Subject to demand, this is the first choice of phasing.

Extended Green: This is only used where;

- (1) the two-way street intersects with a one-way,
- (2) the extended phase improves progression.

Exclusive and Separate/Protected Left Turn: Limited use to multi-lane arterials where the A.D.T. is greater than 25,000.

Note 13
Calgary

Advanced Green: Standard application for left turn phase on one approach.

Leading Simultaneous Left Turn: Standard application for left turn phase on both approaches.

Extended Green: Used only when no opposing left turn movement and when signal coordination indicates it to be more efficient than advanced green. Typical use: diamond interchange.

Lagging Simultaneous Left Turn: Used when coordination parameters make it more suitable than leading simultaneous left turn.

Exclusive/Protected Left Turn: Used for dual turn lanes, and for single turn lanes where incidence of left turn collisions is high.

Separate/Protected Left Turn: Used only if intersection design and traffic flows make standard phasing unsafe or inefficient.

NOTES TO TABLE 4

(Question 1D)

Note 14
Camrose

Advanced Green: This system is the only left-turn phasing system presently being used in Camrose.

Note 15
Edmonton

Partially Protected Left Turns (Advanced or Delayed):

- an exclusive left-turn lane exists
- the queue extends beyond the left-turn lane, thereby blocking the through movement
- intersection geometrics create a visibility problem or hazardous conflicts are observed which would be alleviated by a priority aspect (safety concern)

Protected Left Turns:

- opposing traffic at high speed (over 60 km/h)
- opposing traffic travelling on wide carriageway
- high opposing volume
- high left turn across path accident rate
- inadequate sight distance
- presence of rail vehicles on a median
- the requirement for continuity in the left-turning flow

Note 16
Fort McMurray

Advanced Green: If available gaps do not provide sufficient time to clear left-turn demand within two consecutive cycles.

Note 17
Lethbridge

Advanced Green: Volume;

Leading Simultaneous Left Turn: Volume-observation;

Exclusive/Protected Left Turn: Volume;

Separate/Protected Left-Turn: Volume

Note 18
Medicine Hat

Advanced Green: RTAC Geometric Design Standards;

Leading Simultaneous Left Turn: Each approach considered individually as per RTAC standards;

Exclusive/Protected Left Turn: Not used with fixed time controllers. For left-turn traffic from one approach, advanced green is used. The need for left turn defined by RTAC Geometric Design Standards;

Separate/Protected Left Turn: When traffic from opposing approaches is unbalanced and no left-turn bay is provided.

NOTES TO TABLE 4

(Question 1D)

Note 19
Red Deer

Selection of different types of left-turn phasing are based on (1) design period vehicle arrival pattern and arrival rate, the phasing structure that minimizes total intersection delay will be selected; (2) leading left turns are preferred to lagging left turns for safety reasons; (3) lagging left-turn phases however are preferred at vehicular-activated signals that allow phase skipping.

Note 20
North Battleford

Phasing is based on a 12-hour traffic count.

Note 21
Prince Albert

Advanced Green:

- (1) Volume: where there is a heavy left-turn movement in one direction only and without adequate gaps in opposing direction.
- (2) Accident History: review of number of accidents at an intersection for the past three years.
- (3) Coordination: installing an advance green improves the coordination of a system of traffic signals.

Leading/Simultaneous Left Turn:

- (1) Volume: same as above except that both directions have heavy left turns without adequate gaps in opposing through traffic.

Note 22
Regina

Advanced Green: used where there is a significantly larger number of left-turning vehicles in one direction than the other.

Leading/Simultaneous Left-Turn: used when there is a large number of left-turning vehicles in each direction or where the through traffic is so heavy that the number of vehicles turning left cannot do so during the normal cycle.

Separate/Protected Left Turn: used where no left-turn storage bays are available and opposing traffic prevents safe execution of the left turn.

Note 23
Saskatoon

Advanced Green: preferable in most circumstances. Progression is the main consideration in an interconnected system.

Leading Simultaneous Left Turn: Preferred if both left-turn movements require left-turn phases.

NOTES TO TABLE 4

(Question 1D)

Note 24
Winnipeg

Extended Green: used mainly where progression requires it. Special phasing used for opposing left-turn movements.

Exclusive/Protected Left Turn: used where opposing through traffic operates at a high speed.

Separate/Protected Left Turn: used mainly where progression requires it.

Advanced Green:

- (1) If opposing left turn is allowed - must be advance.
- (2) If it fits into progression better than an extended green.

Leading Simultaneous Left Turn:

- (1) If it fits into progression better than simultaneous lagging green.
- (2) Providing intersection geometry is suitable to accommodate the "Back to Back" left-turn movements.

Extended Green:

- (1) If opposing left turn is prohibited, or
- (2) If intersection is a "T" intersection, eliminating opposing lefts,
- (3) If it fits into progression system better than advance green.

Lagging Simultaneous Left Turn:

- (1) If more suitable to the progression system.
- (2) If geometry is conducive to simultaneous turns.

Exclusive/Protected Left Turn:

- (1) Large volume of left turns
- (2) Large number of opposing vehicles, thereby allowing no gaps
- (3) Opposing traffic 85th percentile speed exceeds 45 miles per hour.

Separate/Protected Left Turn:

- (1) If capacity at intersection is greater ("Push/Pull") using this methodology
- (2) Not often used in Winnipeg. Generally used only for opposing approaches which both have an exclusive and a second optional left-turning lane; where traffic-responsive control is used and where pedestrian traffic in conflict with lefts is prohibited or small in volume.

NOTES TO TABLE 4

(Question 1D)

- (3) "Lead/lag" exclusive protected left turns: A number of intersections utilize "lead/lag" phasing where appropriate for signal progression. In this case, for example, southbound through and left traffic proceed under arrow control, then north/south through traffic receive vertical arrow plus red display, and finally northbound through and left traffic are given concurrent arrow service.

Note 25
Barrie

Advanced Green: MUTCD Section B3.03.01 "Advanced Green".

Exclusive/Protected & Separate/Protected Left Turn: when the left-turn volumes well exceed 2/cycle as per above and a specific phase or phases are required to handle heavy left-turn volumes in both directions. Usually used on major arterials and with fully actuated equipment where phase selection and time allocated are demand-responsive.

Note 26
Belleville

Advanced Green: On the basis of a traffic study.

Exclusive/Protected Left Turn: used at one intersection only when pedestrians request time at a "T" intersection at the "protected" side of the "T".

Note 27
Brantford

Exclusive/Protected Left Turn: warranted through geometrics and volumes.

Note 28
Burlington

Advanced Green: When one direction cannot provide opportunity for more than two left turns per cycle

Leading Simultaneous Left Turn: When two opposing left turns warrant exclusive phases

Note 29
Chatham

Advanced Green: based on past practice

Exclusive/Protected Left Turn: left turns warranted both directions or where opposing left-turn storage lanes permit simultaneous lefts

Note 30
Cornwall

Advanced Green: used wherever extended greens are not feasible.

Extended Green: provided when an exclusive left-turn lane with adequate storage is available and there are no opposing left turns.

NOTES TO TABLE 4

(Question 1D)

Note 31
Durham (R.M.)

Advanced Green: separate left-turn lane if actuated.

Leading Simultaneous Left Turn

- i) separate left-turn lanes
- ii) balanced left-turn demand from opposing direction.

Extended Green: one-way street intersection.

Note 32
Guelph

Advanced Green: often depends on the existing equipment and its capabilities - if the left turn is one of the heaviest movements, an advanced green is used at fixed time control locations.

Extended Green: 3 intersections within the City work with extended (or delayed) green. All intersections have geometric problems and for added safety, 2 amber intervals are required.

Exclusive/Protected Left Turn: 4 intersections, opposing left-turns are equal. There is a demand for both directions to have necessary left-turn timing. Timing is based on minimum-maximum intervals. Intersections were designed for this system.

Note 33
Hamilton

Advanced Green:

- 1) minimum 100-120 turns/hr
- 2) queuing study indicates vehicles are delayed to third cycle or more
- 3) no solution through simple adjustment of split.

Exclusive/Protected Left Turn:

- 1) visibility constraint
- 2) balanced left-turn volumes

Separate/Protected Left Turn

- 1) visibility constraint
- 2) unbalanced left-turn volumes - only used in conjunction with Exclusive/Protected Left Turn.

Note 34
Kingston

Simultaneous Left Turn: 4 lanes or more plus 2 or more vehicles per cycle in each opposing direction

Separate/Protected Left Turn: More than 2 vehicles per cycle and field observations.

NOTES TO TABLE 4

(Question 1D)

Note 35
Kirkland Lake

Advanced Green: demand volume exceeds the larger value on chart 31 - MTC Manual.

Leading Simultaneous Left Turn: both opposing left-turn demand volumes exceeds values of Chart 31.

Note 36
London

(i)-(vi): Intersection operating characteristics are examined and applied to the (Ewens) capacity manual.

Note 37
Mississauga

Advanced Green: Accident concerns considered.

Leading Simultaneous Left Turn: Warrant for advanced green in both directions met.

Exclusive/Protected Left Turn: Warrant for separate left turn in both directions - multi-lane available.

Separate/Protected Left Turn: Accident experience coupled with a warrant for a separate phase - two lanes turning left.

Note 38
Oakville

Advanced Green: up to a 40 controller.

Leading Simultaneous Left Turn: all 60-80 controllers.

Note 39
Orillia

RTAC Geometric Standards for Canadian Roads and Streets guidelines:

- a) If left-turning traffic is less than 100 v/h and opposing traffic is more than 450 v/h, provide a left-turn lane without a separate phase.
- b) If left-turning traffic is greater than 100 v/h and opposing traffic is less than 450 v/h, provide a left-turn lane without a separate phase.
- c) If left-turning traffic is greater than 100 v/h and opposing traffic is greater than 450 v/h, provide a left-turn lane and a separate phase.

Existing width and environment surrounding intersection determine whether separate lane can be provided.

NOTES TO TABLE 4

(Question 1D)

Note 40
Ottawa-Carleton (R.M.)

Advanced Green - Normally used when opposing left-turn movement is permitted, advanced greens are preferred when there is no left-turn lane and approach storage is limited.

Leading Simultaneous Green - Used when left-turn phasing is warranted for both opposing directions and the left-turn demand for each direction is approximately equal.

Extended Green - Only used if opposing left-turn is banned. Preferred in coordinated systems as delay to left-turning traffic is reduced.

Lagging Simultaneous Left Turn - Same as Leading Simultaneous left turn. Lagging simultaneous left turn preferred at coordinated signals.

Exclusive/Protected Left Turn - Used when left-turning traffic has poor visibility of opposing traffic or accident records otherwise indicate a large number of accidents involving turning vehicles and opposing traffic.

Separate/Protected Left Turn - Used when protected left-turn phasing is warranted and intersection efficiency is increased through the use of shared through and left-turn lanes.

Note 41
Peel (R.M.)

Advanced Green: when there is assistance required in only one direction.

Leading Simultaneous Left Turn: when the left-turn demand in both directions is heavy and assistance is required.

Separate/Protected Left Turn: when there is a need for dual left-turn lanes.

Note 42
St. Thomas

MTC Traffic Control Signal Timing and Capacity Manual.

Note 43
Sault Ste. Marie

Advanced Green: compliance with the HCM formula and more than 2 vehicles per cycle turning left and/or no less than 100 left turns per hour and number of lanes permit separate left turn in the case of opposite left turns.

Leading Simultaneous Left Turn: volumes as above but for opposing approaches and lanes are available.

Extended Green: not normally used except for two intersections which are too close but are located at a pair of one-way streets.

NOTES TO TABLE 4

(Question 1D)

Note 44
Sudbury

Advanced Green: installed where there are more than two vehicles per cycle and the sum of left turns plus opposing through traffic exceeds 1200 vph.

Leading Simultaneous Left Turn: volume requirement as for Advanced Green, and where opposing volumes and required pedestrian clearances allow for suitable gaps to be utilized by turning vehicles.

Extended Green: not used except at fully actuated "T" intersections.

Separate/Protected Left Turn & Exclusive/Protected Left Turn: where capacity and/or physical configuration dictates.

Note 45
Thunder Bay

Advanced Green: If 15% of approach volume turns left and observations indicate a need.

Note 46
Toronto (Metro)

Advanced Green: Traffic Control Centre Guidelines.

Leading Simultaneous Left Turn: Traffic Control Centre Guidelines plus: where there is a constant (all periods) opposing left-turn demand with moderate through volumes - only 10 locations have this type of control in Metropolitan Toronto.

Extended Green: Not used for reasons of safety and standardization. The safe clearance of opposing traffic, especially left turns is lengthy, and for this reason, is not practical.

Lagging Simultaneous Left Turn: Not used for the same reasons as for "Extended Green".

Exclusive/Protected Left Turn: This type of controller is applied on a minimal basis (4 intersections in Metro Toronto). It is used for reasons of safety due to geometry or speed limit at the intersection.

Separate/Protected Left Turn: This style of control is used whenever double left turns are permitted.

Note 47
Waterloo (R.M.)

Advanced Green: Canadian MUTCD.

Exclusive/Protected Left Turn: Ontario MUTCD.

NOTES TO TABLE 4

(Question 1D)

Note 48 Windsor	<u>Advanced Green:</u> MUTCD Section B.304 <u>Leading Simultaneous Left Turn:</u> MUTCD Section B.302 and Section 4
Note 49 Anjou	<u>Lagging Simultaneous Left Turn:</u> used with left turn lane vehicle detection
Note 50 Hull	No standards.
Note 51 Joliette	<u>Advanced Green:</u> number of vehicles in intersection and the frequency and duration of accumulation. <u>Leading Simultaneous Left Turn:</u> Same as above.
Note 52 Jonquiere	<u>Advanced Green:</u> The number of turns per cycle and the site conditions <u>Leading Simultaneous Left-Turn:</u> The number per cycle, the site dimensions. Sometimes the types of vehicles <u>Extended Green, Lagging Simultaneous, Exclusive/Protected and Separate/Protected Left Turns:</u> Site observations.
Note 53 Laval	<u>Advanced Green:</u> 1) when the number of left turns is more than 20% of opposing traffic 2) when the number of left turns is more than 100 v/h while the opposing traffic is less than 450 v/h or when the number of left turns is less than 100 v/h while the opposing traffic is more than 450 v/h <u>Leading Simultaneous Left Turns:</u> When the number of left turns from both directions meet the criteria above. <u>Exclusive/Protected Left Turn:</u> 1) when the number of left turns is more than 20% of opposing traffic 2) when the number of left turns is greater than 100 v/h while the opposing traffic is greater than 450 v/h <u>Separate Protected Left Turn:</u> If the traffic volumes differ significantly by direction and the intersection geometry is also considered.

NOTES TO TABLE 4

(Question 1D)

Note 54
Montreal

Advanced Green: 1. Signal coordination, 2. One lane, 3. Low turning volumes with respect to the traffic volume in the same direction (83 locations)

Leading Simultaneous Left Turn: Signal coordination (1 location)

Extended Green: 1. Signal coordination, 2. Accident rate, 3. Pavement width (greater than 3 lanes), 4. No opposing left turn (88 locations)

Lagging Simultaneous Left Turn: 1. Signal coordination, 2. Accident rates, 3. Pavement width (greater than 3 lanes), 4. Balanced traffic volumes (8 locations)

Exclusive/Protected Left Turns: 1. Signal coordination, 2. Accident rates (7 locations)

Note 55
Quebec

According to the Quebec Manual of General Instructions on Traffic Control Devices.

Note 56
Rimouski

According to a study of traffic patterns at each intersection.

Note 57
Saint-Hyacinthe

Advanced Green & Exclusive/Protected Left Turn: Observation of traffic

Note 58
Saint-Laurent

Advanced Green: when available storage area for left turns is reduced - heavy traffic volumes - no exclusive left-turn lane - signal synchronization

Leading Simultaneous Left Turn: Heavy left turns in both directions, insufficient left-turn storage or no exclusive left-turn lane, requires signal synchronization

Extended Green: important left turn movement occurring simultaneously with a permitted right turn in a non-conflicting direction with sufficient storage. Requires signal synchronization.

Lagging Simultaneous Left Turn: heavy left-turn movement with non-conflicting right turns. Sufficiently long storage lanes. Requires signal synchronization.

NOTES TO TABLE 4

(Question 1D)

	<u>Exclusive/Protected Left Turn:</u> heavy left-turn volume with moderate through traffic volumes. Heavy pedestrian movements on secondary road. <u>Separate/Protected Left Turn:</u> Requires signal synchronization (much flexibility)
Note 59 Sherbrooke	<u>Advanced Green:</u> to serve small left-turning volumes; <u>Leading Simultaneous Left Turn:</u> to serve small volumes of left turns when there are moderate opposing left turns; <u>Extended Green:</u> to serve small volumes of left turns and for signal coordination; <u>Lagging Simultaneous Left Turns:</u> same as leading simultaneous left turns and for signal coordination; <u>Exclusive/Protected Left Turns:</u> moderate left-turning volumes to accommodate; <u>Separate/Protected Left Turns:</u> interesting from the point of view of flexibility of the system - also when the volume is moderately high for all approaches.
Note 60 Thetford Mines	Width of intersection and volume of traffic without any such "technique", observation of traffic, counts.
Note 61 Victoriaville	<u>Advanced Green & Extended Green:</u> Observations
Note 62 Fredericton	Generally follow the guidelines set out in the "MUTCD", Canada.
Note 63 Saint John	If field observation indicates a problem, traffic counts are taken (7-11 a.m. & 2-6 p.m.) to determine percentage left-turns (generally 10% of approaching traffic warrants phase).
Note 64 Halifax	No numerical values; after traffic counts and field observations judgment is used as to whether or not the left-turn delays are sufficient to warrant a signal feature. <u>Advanced Green:</u> when the left-turn demand (or delays) from <u>one</u> approach is significant enough throughout the day (or heavy during one or both peak periods) to justify a flashing green indication.

NOTES TO TABLE 4

(Question 1D)

Lagging/Simultaneous Left Turn: significant off-peak demand and peak hour demand from one or both approaches (often the heavy a.m. peak demand is from one direction; the p.m. peak from the other).

Exclusive/Protected Left Turn: only one in the City (at a 3-legged, Y-shaped intersection); originally installed as much to provide a safe pedestrian crossing as to accommodate a modest left-turn demand against heavy opposing flow.

Separate/Protected Left Turn: used in 3 locations where there are dual left turns through wide median intersections; the left-turn demand is very heavy during one of the peak periods and moderate to heavy during the remaining daylight hours.

Note 65
Corner Brook

Advanced Green: used when a significant number of vehicles from one direction will be making a left turn onto a cross-street. Need is identified by field observation.

Leading Simultaneous Left Turn: similar to above when significant number of vehicles from both directions will be making a left turn.

Exclusive/Protected Left Turn: used where high volume of traffic on both main and cross-streets.

Note 66
St. John's

Advanced Green: when one approach has left turns equal or more than 20% of the through volume in the heavy direction.

Leading Simultaneous Left Turn: when opposing approaches have left turns equal to more than 20% of the through volume.

Exclusive/Protected Left Turn: to separate two left-turning lanes from opposing through traffic.

Note 67
British Columbia

Advanced Green: Assessment of left turn and opposing traffic (heavy directional left-turn demand); geometrics (preferably left-turn slots, normally no greater than two opposing lanes); speed (60 km/h or lower); consistency (in order to maintain uniformity); general accident experience;

Leading Simultaneous Left Turn: Contrary to Ministry's interpretation of the British Columbia Motor Vehicle Act;

Extended Green: Rarely used due to safety considerations;

Note 68
Alberta

Lagging Simultaneous Left Turn: Only installed in situations where left turns are made onto a two-way facility separated by a wide median or boulevard and where warranted by volume;

Exclusive/Protected Left Turn: Volumes (i.e. heavy two-directional left turns and opposing volumes), geometrics (two or more opposing lanes, raised median channelization), speed (used at all speeds, however, used exclusively at 70 km/h or greater), uniformity, accident experience;

Separate/Protected Left Turn: Volumes (uniform left and through approach volumes) - installed when left-turning volume exceeds the efficient use of exclusive/protected type phasing, and accident experience - eliminates conflicts between left turning and opposing traffic.

Advanced Green: An advanced green may be used when the left turns from any one of the pair of opposite approaches is not sufficient to justify a complete separate phase, provided that the number of vehicles making the left turn exceeds two vehicles per cycle and the sum of these left turns plus the opposing volume of through traffic exceeds 1200 vehicles per hour of green.

Leading Simultaneous Left Turn: Very seldom used - only if a fully actuated quad phase controller is in use.

Extended Green: This left-turn phasing practice is not used because of its safety concern. The objections to this method are:

- a) Drivers waiting to turn cannot tell when movement from the opposite approach is stopped.
- b) The time for an additional clearance period is required.
- c) Unless a separate turning lane is provided, waiting vehicles reduce the approach capacity.

Lagging Simultaneous Left Turn: This practice has not been used in the past.

Exclusive/Protected Left Turn: This phasing scheme is used extensively at locations where left-turn volumes are high and a separate left-turn lane is provided.

Separate/Protected Left Turn: This phasing scheme not used. If separate/protected left turns are required on all approaches, a quad operation would probably be used.

NOTES TO TABLE 4

(Question 1D)

Note 69
Manitoba

Advanced Green: Used if there is a left turn demand of more than two (2) left-turning vehicles per cycle in one (1) direction only

Lagging Simultaneous Left Turn: Only used to aid in progression of traffic

Exclusive/Protected Left Turn: used at fully actuated signals with heavy left-turning movements

Separate/Protected Left Turn: Provided at fully actuated locations with no opposing demand.

Note 70
Ontario

Advanced Green
Leading Simultaneous Left Turn:

- A. Phasing Based on Traffic Characteristics
Protected/permisive left-turn phasings should be used for all intersection approaches that require a left-turn phasing unless there is a compelling reason for using another type of left-turn phasing. Protected/permisive left-turn phasing is the most common type of left-turn phasing currently in use in Ontario. Drivers favour this type of operation because of the reduction in intersection delay is very noticeable. The traffic engineer should initially operate the left-turn phase as protected/permisive on a trial basis. If unsatisfactory operation results, the protected/permisive left-turn phasing should be converted to another type of left-turn phasing.
- B. Phasing Based on Intersection Design
- (a) Opposing left-turn lanes (span wire installation)
 - (b) Partially offset left-turn lanes with divisional island
 - (c) Wide medians (up to 15 metres) with bullet nose type design
 - (d) Wide medians (median width over 15m). Use advanced green only.

Extended Green
Lagging Simultaneous Left Turns:

- A. Phasing Based on Traffic Characteristics
The above mentioned phasing should be restricted to only the following situations:

- (a) An approach to a "T" intersection, where opposing U-turns are prohibited.
- (b) An approach to a 4-way intersection where the opposing approach has prohibited left turns or protected left-turn phasing
- (c) Opposing approaches to a 4-way intersection where the left-turn volumes from the opposing approach do not substantially differ throughout the various time periods of a normal day.

B. Phasing Based on intersection Design

- (a) Opposing left-turn lanes (span wire installation)
- (*b) Partially offset left-turn lanes with divisional island
 - *Extended Green: Use it only if the left turns facing the extended green are prohibited.
- (*c) Wide medians (up to 15m) with bullet nose type design - *Extended Green: Use it only if the left turns facing the extended green are prohibited.
- (d) Wide medians (median width over 15m) - Use extended green only.

Exclusive Protected Left Turn:

A. Phasing Based on Traffic Characteristics

It should be provided when one or more of the following conditions exist:

- (a) poor sight distance for the opposing traffic because of geometrics
- (b) operating speed of the opposing traffic is greater than 70 km/h
- (c) left-turning vehicles must cross three or more lanes of the opposing through traffic
- (d) when protected/permissive left-turn phasing is currently in use and the number of accidents on this approach exceeds 5 accidents per year
- (e) the intersection geometrics is forcing the traffic engineer to provide the left-turn driver with an exclusive signal head that cannot be shared with the adjacent through movement
- (f) when the sign to opposing traffic is less than 85 m when the opposing traffic is travelling less than 70 km/h (restricted flow condition) or less than 125 m, when the opposing traffic is travelling at 70 km/h or more (free flow condition). This represents approximately 5 seconds of travel time which corresponds to a gap size universally accepted by left-turn drivers.

- (g) when exclusive double left-turn lanes are in operation.

B. Phasing Based on Intersection Design

- (a) Opposing left-turn lanes (span wire installation)
- (b) Partially offset left-turn lanes with divisional island
- (c) wide medians (up to 15 m median width) with bullet nose type design
- (d) adjacent left-turn lanes without divisional island (span wire install)
- (e) totally offset left-turn lanes with divisional island
- (f) wide medians (median width over 15 m)

Separate (Protected) Left Turns:

A. Phasing Based on Traffic Characteristics

It should be used if one or more of the following conditions exist:

- (a) Opposing approaches are offset to an extent that simultaneous left turns from opposing directions would be impossible or hazardous (i.e. wide medians over 15 m median width).
- (b) left-turning volume is extremely heavy on an approach that does not have an adequate length of a separate left-turn lane.
- (c) Drivers are permitted to turn left from more than one lane, and the drivers are also permitted to use the right-turn lane as a through lane.

B. Phasing Based on Intersection Design

- (a) Opposing left-turn lanes (span wire installation)
- (b) Partially offset left-turn lanes with divisional island
- (c) Wide medians (up to 15 m median width) with bullet nose type design
- (d) Adjacent left-turn lanes without divisional island (span wire install)
- (e) Totally offset left-turn lanes with divisional island
- (f) Wide medians (median width over 15 m).

Note 71
Quebec (Prov.)

Advanced Green: When the level of service in one approach is inferior to the level of service in another direction.

Leading Simultaneous Left Turn: Exclusive left turning lanes with equal levels of left turns in both directions

NOTES TO TABLE 4

(Question 1D)

Extended Green: Not yet utilized, used only with synchronized signal systems taking into account the arrival of left-turn vehicles

Lagging Simultaneous Left Turns: similar to leading simultaneous left turns and a function of other constraints, such as for purposes of signal synchronization or the occurrence of left turns.

Exclusive/Protected Left Turns: exclusive left-turn lanes on a divided roadway

Separate/Protected Left Turn: number of left turns per lane is equal to through traffic for the approach or when the volume of left turns on an approach is much larger than the left turns from the opposite approach.

Note 72
New Brunswick

Very limited use - no guidelines formulated.

Note 73
Nova Scotia

Advanced Green: Heavy left turns, one direction;

Leading Simultaneous Left Turns: Heavy left turns on the two approaches;

Extended Green: Low volume left turns and high volume of through traffic;

Lagging Simultaneous Left Turn: In conjunction with simultaneous advance left turns where there are high volume left turns on all four approaches, otherwise not used;

Exclusive/Protected Left Turn: Heavy left turns on the two approaches.

TABLE 5

(Question 2A)

**VEHICLE CLEARANCE INTERVAL
AMBER OR AMBER PLUS ALL RED
DETERMINED BY**

Province and City or Region	Canadian Manual Uniform Traffic Control Devices	Ontario Manual Uniform Traffic Control Devices	Trans'n & Traffic Engineering Handbook	Ontario Ministry of Transportation and Communications Method of Signal Timing	Other
British Columbia					
Burnaby (D)	X		X		
Coquitlam (D)	X				
Kamloops			X		
Langley	X				
Maple Ridge (D)	X				
Matsqui (D)	X				
Nanaimo	X				
Prince George	X				
Saanich (D)	X				
Surrey (D)	X				
Trail					Note 1
Vancouver	X		X		
Victoria					Note 2
Alberta					
Calgary					Note 3
Camrose					Note 4
Edmonton					Note 5
Fort McMurray					Note 6
Lethbridge	X				Note 7
Medicine Hat	X				
Red Deer					Note 8
Saskatchewan					
North Battleford	X				
Prince Albert	X				
Regina					Note 9
Saskatoon					Note 10
Manitoba					
Brandon					Note 11
Winnipeg					Note 12

(D) - District

TABLE 5
(continued)

(Question 2A)

VEHICLE CLEARANCE INTERVAL
AMBER OR AMBER PLUS ALL RED
DETERMINED BY

Province and City or Region	Canadian Manual Uniform Traffic Control Devices	Ontario Manual Uniform Traffic Control Devices	Trans'n & Traffic Engineering Handbook	Ontario Ministry of Transportation and Communications Method of Signal Timing	Other
Ontario					
Barrie	X				
Belleville	X				
Brantford	X				
Burlington				X	
Chatham			X		
Cornwall		X			Note 13
Durham (R.M.)		X			
Guelph	X		X		Note 14
Hamilton		X			Note 15
Kingston	X				
Kirkland Lake				X	
London		X			
Mississauga	X				Note 16
Oakville					Note 17
Orillia		X			Note 18
Ottawa-Carleton (R.M.)		X			
Peel (R.M.)		X			
St. Thomas		X			
Sarnia	X				
Sault Ste. Marie				X	
Sudbury		X			
Thunder Bay					Note 19
Toronto (Metro)					Note 20
Wallaceburg		X			
Waterloo (R.M.)	X				
Windsor	X				
Quebec					
Hull	X				
Jonquiere					Note 21
Laval	X		X		Note 22
Montreal			X		
Quebec					Note 23

(R.M.) - Regional Municipality

TABLE 5
(continued)

(Question 2A)

**VEHICLE CLEARANCE INTERVAL
AMBER OR AMBER PLUS ALL RED
DETERMINED BY**

Province and City or Region	Canadian Manual Uniform Traffic Control Devices	Ontario Manual Uniform Traffic Control Devices	Trans'n & Traffic Engineering Handbook	Ontario Ministry of Transportation and Communications Method of Signal Timing	Other
Quebec (cont'd)					
Rimouski			X		
Saint-Hyacinthe					Note 24
Saint-Laurent	X				Note 25
Sherbrooke			X		
Thetford Mines					Note 26
Victoriaville					Note 27
New Brunswick					
Fredericton	X				
Nova Scotia					
Halifax	X		X		Note 28
Newfoundland					
Corner Brook	X				
St. John's	X			X	
Provincial					
British Columbia			X		
Alberta	X				Note 29
Manitoba					Note 30
Ontario				X	
Quebec			X		
New Brunswick			X		
Nova Scotia	X				

NOTES TO TABLE 5

- Note 1 Trail - Not used.
- Note 2 Victoria - Based on public criticism and normal manuals generated amber varying from 3 seconds to 6 seconds. A standard 4 second amber has been adopted, plus all-reds as required for extra clearance.
- Note 3 Calgary - Local observations: Standard amber is 4 seconds. If required clearance is longer, all-red is used.
- Note 4 Camrose - Capacity of Traffic Signals Course, University of Alberta, 1982.
- Note 5 Edmonton - Intergreen interval consists of amber plus an all red interval. The length of amber is fixed by the requirements of driver perception and reaction time.

<u>Speed</u>	<u>Required Amber</u>
50 km/hr or less	3 seconds
60 km/hr	4 seconds
70 km/hr or more	5 seconds

The all red interval provides the remainder of the required clearance interval, with a normal 1 second minimum value.

The basis of the intergreen calculations is as follows:

1. Vehicle in clearance/vehicle approaching
2. Vehicle clearing/pedestrian approaching

- Note 6 Fort McMurray - Saturation Flow Manual, City of Edmonton Operations Section and the University of Alberta Transportation Engineering Group.
- Note 7 Lethbridge - A maximum of 4 seconds amber with 1 second All-red.
- Note 8 Red Deer - Design speed and associated acceleration/deceleration rate, reaction/perception time and clearance path length, etc.
- Note 9 Regina - We use a standard 3.5 second amber and 1.5 second all-red clearance at the large majority of intersections.
- Note 10 Saskatoon - 4.0 sec amber plus a variable all-red. Total clearance interval calculated using Edmonton's method.

NOTES TO TABLE 5

- Note 11 Brandon - 4.0 sec - 66' R.O.W. - has been used since 1965.
- Note 12 Winnipeg - A standard 4 seconds, or as close to, but never less than, 4 seconds of amber, as possible. A very few locations have 5 seconds amber. A standard of either 2 per cent, or 2 seconds, as the case may be, is utilized as an additional "All Red" interval where opposing through traffic speed exceeds 45 mph.
- Note 13 Cambridge - Modification of Ontario MUTCD: vehicle clearance interval = $1.5 + .05s + 0.7 W/S$, where S = approach speed (mph), W = width of intersection (ft) + avg. vehicle length (20 ft).
- Note 14 Guelph - A combination of Canadian MUTCD and the Transportation and Traffic Engineering Handbook; however, the majority of intersections have a 4-second amber and a 2-second all-red due to the simplicity of the electromechanical controller vs. solid state.
- Note 15 Hamilton - Revised Ontario MUTCD formula as per MTC directive of 81 04 10. Times adjusted slightly to fit electromechanical equipment.
- Note 16 Mississauga - Essentially based on the Canadian MUTCD, a policy has been established.
- Note 17 Oakville - 4 second amber, 2 second all-red.
- Note 18 Orillia - Amber minimum of 4 seconds is favoured with an additional 1-2% of the cycle designated to an all-red condition.
- Note 19 Thunder Bay - 4 seconds plus 2 seconds all-red.
- Note 20 Toronto (Metro) - Length of amber is determined for each intersection approach (or phase) based on speed limit, geometry (vertical and horizontal), Metro area, and type of roadway. Usually 4.0 seconds is the standard.
- Note 21 Jonquiere - The permitted approach speeds. The site geometry (e.g. - slope or gradient).
- Note 22 Laval - Route Capacity
- Note 23 Quebec - According to the Quebec Manual of General Instructions on Traffic Control Devices.

NOTES TO TABLE 5

- Note 24 Saint-Hyacinthe - Visual observations
- Note 25 Saint-Laurent - All road dimensions and speeds (50 km/h) are usually constant. Therefore, standardized clearance interval of 4 seconds is used, based on the manual.
- Note 26 Thetford Mines - The demand for safety, the intersection geometrics and the speed of traffic on arterials.
- Note 27 Victoriaville - Observations.
- Note 28 Halifax - Both of the sources are used, but the handbook has been used as the primary source over the last several years.
- Note 29 Alberta - Where the use of a clearance period longer than 4.5 seconds is required, the Department splits the time into 2 parts, namely an amber interval of approximately 4 seconds and an all-red interval of the necessary length to make up the total required time.
- Note 30 Manitoba - Standard amber period of 4 seconds used throughout the Province. When All-Red clearance is provided an interval of 2 seconds is used.

TABLE 6

(Question 2B)

USE OF "ALL-RED" VEHICLE CLEARANCE INTERVAL

Province and City or Region	At Selected Intersections Assessed Individually	At All Intersections (or will be)	Notes (See Attached Sheets)
British Columbia			
Burnaby (D)	X		Note 1
Coquitlam (D)	X		Note 2
Kamloops		X	Note 3
Langley	X		Note 4
Maple Ridge (D)		X	
Matsqui (D)		X	
Nanaimo	X		
Prince George	X		Note 5
Saanich (D)		X	
Surrey (D)		X	
Trail			Note 6
Vancouver	X		Note 7
Victoria	X		Note 8
Williams Lake			Note 9
Alberta			
Calgary	X		Note 10
Camrose		X	Note 11
Edmonton		X	
Fort McMurray		X	Note 12
Lethbridge		X	Note 13
Medicine Hat		X	Note 14
Red Deer	X		Note 15
Saskatchewan			
North Battleford			Note 16
Prince Albert	X		
Regina		X	
Saskatoon	X		Note 17
Manitoba			
Brandon		X	Note 18
Winnipeg	X		Note 19

(D) - District

TABLE 6
(continued)

(Question 2B)

USE OF "ALL-RED" VEHICLE CLEARANCE INTERVAL

Province and City or Region	At Selected Intersections Assessed Individually	At All Intersections (or will be)	Notes (See Attached Sheets)
Ontario			
Barrie		X	Note 20
Belleville		X	Note 21
Brantford	X		
Burlington		X	
Chatham		X	
Cornwall		X	Note 22
Durham (R.M.)		X	Note 23
Guelph		X	Note 24
Hamilton		X	Note 25
Kingston	X		
Kirkland Lake		X	Note 26
London	X		Note 27
Mississauga		X	Note 28
Oakville		X	Note 29
Orillia	X		
Ottawa-Carleton (R.M.)		X	Note 30
Peel (R.M.)		X	
St. Thomas		X	Note 31
Sarnia		X	
Sault Ste. Marie		X	Note 32
Sudbury		X	Note 33
Thunder Bay		X	Note 34
Toronto (Metro)		X	Note 35
Wallaceburg		X	Note 36
Waterloo (R.M.)		X	
Windsor		X	Note 37
Quebec			
Anjou		X	
Hull	X		
Joliette	X		Note 38
Jonquiere		X	
Laval	X		
Montreal	X		Note 39
Quebec			Note 40
Rimouski	X		
Saint-Hyacinthe	X		Note 41

(R.M.) - Regional Municipality

TABLE 6
(continued)

(Question 2B)

USE OF "ALL-RED" VEHICLE CLEARANCE INTERVAL

Province and City or Region	At Selected Intersections Assessed Individually	At All Intersections (or will be)	Notes (See Attached Sheets)
Quebec (cont'd)			
Saint-Laurent		X	Note 42
Sherbrooke	X		Note 43
Thetford Mines	X		Note 44
Victoriaville	X		
New Brunswick			
Fredericton	X		
Nova Scotia			
Halifax	X		Note 45
Prince Edward Island			
No responses			
Newfoundland			
Corner Brook	X		
St. John's		X	
Provincial			
British Columbia	X		Note 46
Alberta		X	Note 47
Manitoba	X		Note 48
Ontario		X	Note 49
Quebec	X		Note 50
New Brunswick	X		
Nova Scotia	X		

NOTES TO TABLE 6

- Note 1 Burnaby (D) - Normally use all red intervals only when the clearance interval exceeds 4 seconds.
- Note 2 Coquitlam (D) - "All-Red" is used extensively in municipalities in the lower mainland of British Columbia and seems necessary due to the driver behaviour. However, it is likely drivers have conditioned themselves to dependency on the "all-red". (Opinion of respondent, having worked in several jurisdictions in Canada.)
- Note 3 Kamloops - "All-Red" should be maximum of 2 seconds to avoid motorists running the light.
- Note 4 Langley - Used at most intersections. Not normally used on electromechanical controllers - particularly GE Type F semi-actuated. "I believe that it is often over-used - should not exceed 1 second" (i.e. should not be long enough to cause drivers to become irritated). Should reduce amber clearance interval in some cases.
- Note 5 Prince George - Only used in CBD for "All Pedestrian" Phase.
- Note 6 Trail - Not used.
- Note 7 Vancouver - All-red intervals are more effective if they are not too long (<1.5 seconds).
- Note 8 Victoria - Resulted in selected areas 20-30% reduction in right angle accidents.
- Note 9 Williams Lake - All-red interval plugs traffic.
- Note 10 Calgary - Longer clearance intervals encourage more vehicles to run through intersection.
- Note 11 Camrose - Some objection at first from police and public. Satisfied with the all-red clearance and although not yet statistically proven, believe to be much safer.
- Note 12 Fort McMurray - Once motorists are aware of the "all-red", the amber becomes less effective and clearing left turns are decreased.
- Note 13 Lethbridge - Use this rather than extended amber clearance interval.
- Note 14 Medicine Hat - All-red should be short, not in lieu of amber.

NOTES TO TABLE 6

- Note 15 Red Deer - All-red intervals are calculated to provide vehicle clearance time.
- Note 16 North Battleford - 1 second all-red.
- Note 17 Saskatoon - "All-red" is more effective in clearing the intersection than a long amber. Too long all-red interval creates driver uncertainty for next phase.
- Note 18 Brandon - Will commence use of "all-red" in 1984.
- Note 19 Winnipeg - (1) For the most part, accidents have not been reduced where all-reds are used, especially at urban intersections, based on collision comparison of 4 to 10 year "Before" and "After" collision statistics. (2) Drivers become familiar with all-red locations and tend to violate reds. (3) Used mainly on high speed roadways away from high volume ambers. (4) Used mainly also at traffic actuated intersections.
- Note 20 Barrie - Very satisfactory and has eliminated most court cases involving running amber when opposing traffic had a green light.
- Note 21 Belleville - A must for safety.
- Note 22 Cornwall - This practice was initiated in the mid-1970's to increase the effective separation between potentially conflicting movements and thereby minimize collision potential.
- Note 23 Durham (R.M.) - If all-red is too long, drivers tend to use it as an extension of the amber clearance interval.
- Note 24 Guelph - Have never examined all-red experience in Guelph.
- Note 25 Hamilton - Overall percentages of "run-red" and "run-red" right-angle collisions are down.
- Note 26 Kirkland Lake - Definitely required especially at saturated intersections as some motorists fully use the amber.
- Note 27 London - If a clearance interval greater than 5 seconds is required, a minimum all-red interval of 1.5 seconds is provided within the vehicle clearance interval.
- Note 28 Mississauga - Safeguard for amber - Improves accident incidence.
- Note 29 Oakville - Works well as a safety clearance.

NOTES TO TABLE 6

- Note 30 Ottawa-Carleton (R.M.) - In accordance with the February 1982 revisions to the Ontario Manual of Uniform Traffic Control Devices, all red clearance intervals are being introduced at all intersections. We have adopted a policy of adding all red intervals when other controller work is required or if the location has been identified as being particularly hazardous.
- Note 31 St. Thomas - Police department does not recognize the all-red as part of clearance interval - treated as a red light.
- Note 32 Sault Ste. Marie - Increases safety at signalized intersections.
- Note 33 Sudbury - Tends to encourage use of amber. All-red must be kept short in order to reduce this problem.
- Note 34 Thunder Bay - It does not seem to have caused problems. Cannot compare the number of red light violations of uninvolved vehicles to the number of accidents.
- Note 35 Toronto (Metro) - Length of "All-Red" is determined by intersection size, shape ("T" intersections have a shorter amber and a longer "All-Red"), congestion within the intersection, particularly that caused by left turns clearing at the end of a permissive green phase. The length of the "All-Red" is varied for different periods of the day.
- Note 36 Wallaceburg - Works well.
- Note 37 Windsor - Allows a more positive direction for police enforcement.
- Note 38 Joliette - Less risk of collision.
- Note 39 Montreal - Application of "All-Red" restricted to locations where the clearance interval is greater than 5 seconds.
- Note 40 Quebec - Not used.
- Note 41 Saint-Hyacinthe - Reduces the number of vehicle conflicts.
- Note 42 Saint-Laurent - Given habits of motorists, this configuration permits us to make safer intersections. Red light is much more understood and respected than a yellow light.
- Note 43 Sherbrooke - Used in a few instances - is a dangerous practice which causes accidents.

NOTES TO TABLE 6

- Note 44 Thetford Mines - Prefer to use a very long amber interval.
- Note 45 Halifax - 37 of 89 signalized intersections have all-red clearances; in general, they occur across wide intersections where the recommended (or calculated) clearance interval would be greater than 5 seconds (although recently narrow intersecting streets with heavy right-angle accident rates have had all-red intervals implemented.
- Note 46 British Columbia - Typically used when clearance interval exceeds 5.0 seconds, and for exclusive/protected left-turn phasing. Found to be effective at intersections that satisfy the above requirements.
- Note 47 Alberta - The all-red clearance interval helps keep the amber interval at a reasonable length; and prevents vehicles from running the amber.
- Note 48 Manitoba - Used mainly at intersections with approach speeds of 70 km/h or greater. It has been found that arbitrary use tends to lead to "running" of signals.
- Note 49 Ontario - Cuts down angle collisions; provides more orderly movement by permitting left-turning traffic to clear the intersection before the next phase comes on; shorter amber interval discourages the use of amber as extension of green time; it may have an adverse effect on red violation. This will be studied in the future.
- Note 50 Quebec (Prov.) - All-red is used only when the anticipated approach speed is greater than 70 km/h.

(Question 3)

TABLE 7

FLASHING (RED-AMBER) OPERATION OF TRAFFIC SIGNALS

Province and City or Region	Mode of Operation Not Used at any Inter- sections	Used at Less Than 5% of Inter- sections	This Mode Used Extensively At: (D.T. = Day Time) (N.T. = Night Time)				In Determining Use of This Mode of Operation Intersections Assessed: Indivi- dually	on System/ Area Basis	
			CBD	Inner City	Sub- urban	Rural			
British Columbia									
Burnaby (D)	X								
Coquitlam (D)		X							
Kamloops	X							X	
Langley								X	
Maple Ridge (D)				N.T.		N.T.			
Matsqui (D)	X								
Nanaimo	X								
Prince George		X		N.T.		N.T.		X	
Saanich (D)								X	
Surrey (D)	X			N.T.		N.T.			
Trail									X
Vancouver	X								
Victoria	X								
Williams Lake								X	
Alberta									
Calgary									
Camrose	X					N.T.		X	
Fort McMurray						N.T.			X
Lethbridge									X
Medicine Hat						N.T.			
Red Deer		X				N.T.		X	

(D) - District

TABLE 7
(continued)

FLASHING (RED-AMBER) OPERATION OF TRAFFIC SIGNALS

Province and City or Region	Mode of Operation Not Used at any Inter- sections	Used at Less Than 5% of Inter- sections	CBD	This Mode Used Extensively At: (D.T. = Day Time) (N.T. = Night Time)			In Determining Use of This Mode of Operation Intersections Assessed: Indivi- dually	on System/ Area Basis
				Inner City	Sub- urban	Rural		
Saskatchewan								
North Battleford			N.T.			N.T.	X	X
Prince Albert								
Regina	X							
Saskatoon			N.T.					X
Manitoba								
Brandon								
Winnipeg	X		DT, NT	DT, NT	DT, NT		X	
Ontario								
Barrie		X					X	
Belleville		X			DT, NT		X	
Brantford		X					X	
Burlington		X		N.T.			X	
Chatham		X					X	
Cornwall		X					X	
Durham (R.M.)	X				N.T.			
Guelph			N.T.	N.T.			X	
Hamilton				N.T.	N.T.		X	
Kingston				N.T.			X	
Kirkland Lake	X							X

(R.M.) - Regional Municipality

(Question 3)

TABLE 7
(continued)

FLASHING (RED-AMBER) OPERATION OF TRAFFIC SIGNALS

Province and City or Region	Mode of Operation Not Used at any Inter- sections	Used at Less Than 5% of Inter- sections	CBD	This Mode Used Extensively At: (D.T. = Day Time) (N.T. = Night Time)		In Determining Use of This Mode of Operation Intersections Assessed: Indivi- dually	on System/ Area Basis
				Inner City	Sub- urban	Rural	
Ontario (cont'd)							
London	X				N.T.		
Mississauga		X					X
Oakville	X						X
Orillia		X	N.T.	N.T.			
Ottawa-Carleton (R.M.)							
Peel (R.M.)	X		N.T.	N.T.	N.T.	N.T.	X
St. Thomas							X
Sarnia							
Sault Ste. Marie	X						
Sudbury		X					X
Thunder Bay				N.T.			
Toronto (Metro)	X						
Wallaceburg			N.T.	N.T.			X
Waterloo (R.M.)		X					X
Windsor	X						
Quebec							
Anjou	X						
Hull		X				N.T.	X
Joliette		X		N.T.			X
Jonquiere			N.T.				
Laval	X						X

(R.M.) - Regional Municipality

TABLE 7
(continued)

(Question 3)

FLASHING (RED-AMBER) OPERATION OF TRAFFIC SIGNALS

Province and City or Region	Mode of Operation Not Used at any Inter- sections	Used at Less Than 5% of Inter- sections	This Mode Used Extensively At: (D.T. = Day Time) (N.T. = Night Time)			In Determining Use of This Mode of Operation Intersections Assessed: Individually or System/ Area Basis
			CBD	Inner City	Sub- urban	Rural
Quebec (cont'd)						
Montreal			N.T.			X
Quebec				N.T.	N.T.	
Rimouski		X			DT, NT	X
Saint-Hyacinthe	X					
Saint-Laurent	X		DT, NT	DT, NT	DT, NT	DT, NT
Sherbrooke	X					
Thetford Mines		X			N.T.	
Victoriaville	X					X
New Brunswick						
Fredericton						
Saint John			N.T.	N.T.	N.T. N.T.	X N.T.
Nova Scotia						
Halifax			N.T.	N.T.	N.T.	
Prince Edward Island						
Charlottetown		X	N.T.			X
Newfoundland						
Corner Brook			N.T.	N.T.		X
St. John's			N.T.		N.T.	X

TABLE 7
(continued)

FLASHING (RED-AMBER) OPERATION OF TRAFFIC SIGNALS

Province and City or Region	Mode of Operation Not Used at any Inter- sections	Used at Less Than 5% of Inter- sections	This Mode Used Extensively At:			In Determining Use of This Mode of Operation Intersections Assessed: Indivi- dually
			CBD	Inner City	Sub- urban	on System/ Area Basis
Provincial						
British Columbia						
Alberta	X	X	N.T.	N.T.	N.T.	X
Manitoba		X				X
Ontario	X					
Quebec		X				X
New Brunswick					N.T.	X
Nova Scotia	X				N.T.	X

**CRITERIA USED TO DETERMINE
THE NEED FOR FLASHING OPERATION
OF TRAFFIC SIGNALS**

Coquitlam (D)	Not used as most signals are fully-actuated micro-processor-based controllers which dwell on main street green in off-peak.
Langley	Fixed time signals are all equipped for flashing operation at night. Fully actuated signals are not, but some consideration has been given to conversion. Generally, do not want late night traffic to have to wait appreciably when there is no cross-traffic.
Maple Ridge (D)	Low volumes, low accident statistics.
Prince George	Extremely light nighttime traffic.
Saanich (D)	Analysis of daily traffic volumes.
Surrey (D)	1) controller malfunction; 2) temporary hazard (e.g. construction in intersection).
Trail	Analysis of traffic volumes.
Vancouver	Red/amber flash is used as a malfunction display for some signals.
Victoria	(1) The flashing mode is used only during equipment failure. (2) Tests of other usage resulted in an increase in accident rates for that period.
Williams Lake	Used from midnight to dawn to eliminate waiting time.
Fort McMurray	Traffic volumes, time of day, sight restrictions and perceived risk of vehicle collision to the motorist at the intersection.
Lethbridge	Used only in CBD - very low traffic volume.
Medicine Hat	Traffic volume at "fixed time" intersections.
Red Deer	(1) Signal must be in normal operation (Red-Amber-Green) for at least 8 continuous hours of the day. (2) Maximum vehicular volume for: major approach 500 vph or less; minor approach 150 vph or less.
North Battleford	Used at night-time only 1:00 a.m. - 6:00 a.m.

(D) - District

Prince Albert	Utilized between 2 a.m. and 6 a.m. in the CBD (extremely low volumes which do not warrant traffic signal controls) where traffic signals are "fixed time" controllers.
Saskatoon	CBD, non-arterial streets, "fixed time" controllers, low volumes. Currently reviewing the benefits of flashing operation during low volume periods.
Winnipeg	(1) Volumes - especially of minor cross-streets - are studied. (2) Shopping centre signals - coincide with opening and closing hours. (3) School signals - coincide with "In" - "Out" times of students. (4) Intersections spaced poorly for signal progression are first priority for assessment as flashing candidates. At these locations, flashing operation intervals are maximized to the greatest extent possible. (5) More locations have been, and will continue to be, looked at with a view to part-time flashing operation. This is being done primarily in order to eliminate unnecessary delays and stops to motorists.
Barrie	This type of operation relates to older installations where the evening off-peak flows were low and there were no demand-responsive capabilities with the traffic controller and intersection. With the implementation of semi-actuated and actuated electronic equipment and detector loops, it seems unnecessary to go to flashing operation during off-peaks particularly when motorists are often confused by this type of signal operation.
Belleville	Analysis of accident statistics.
Brantford	Low cross-street volumes in evening period.
Burlington	Only applied with electro-mechanical controllers.
Chatham	Utilized at isolated intersections with "fixed timed" mode. Where traffic volumes are light.
Durham (R.M.)	See attached warrant sheet. Warrants have been adopted for various circumstances. The factors considered are type of traffic control (fixed time or actuated), traffic volumes, collisions, speed limit, pedestrians, sight distances as well as system considerations. Existing night flash locations are under review. Early morning volumes on the weekend and one early morning shift changes during the week result in only a few hours each night during which night flash is warranted at some locations.

Guelph

Traffic volumes are low, pedestrian activity is low. Normally used in areas where the pedestrian activity is extremely high during the day and evening hours and drops substantially during the night hours (12:00 a.m. - 7:00 a.m.). This topic is presently under review by the City.

Hamilton

Not installed if:

- 1) on one-way street
- 2) intersection of major arterials
- 3) railway or fire pre-emption location
- 4) location with visibility problem
- 5) location with 24-hour collision rate above normal, or
- 6) very wide or channelized

Regularly monitor night flash location collision rates and remove those which exhibit abnormal rates compared to overall rate for all signals during night-flash hours.

Kingston

(Snow removal route and main route to 401). Used where there is minimum side street traffic and delay to the through street is not justified. No statistical criteria.

Snow removal route was chosen to provide minimum delay to trucks and hence use fewer trucks during snow removal carried out between midnight and 7 a.m. "Fixed time" controllers only.

London

The flashing operation of traffic signals is not viewed as a positive type of routine traffic control.

Mississauga

Not in favour of use. Actuated equipment provides reasonable control.

Orillia

Traffic volumes and pedestrian volumes for night operation.

Ottawa-Carleton (R.M.)

Traffic signals may be placed on flashing operation if vehicle volumes on major street or minor street falls below the following hourly vehicular volumes for six or more continuous hours.

	<u>Major Street</u>	<u>Minor Street</u>
One Lane	250	75
Two Lanes	300	100

This is not an automatic warrant. Other factors which must be considered are:

- (a) Intersection location - isolated or synchronized - in a synchronized network of traffic signals it is safer and more efficient to maintain normal operation.
- (b) Flashing amber/red operation is not considered beneficial at semi- or fully-actuated signals.

(R.M.) - Regional Municipality

- (c) Pedestrian safety
- (d) Accident history
- (e) Intersection geometry and driver sight distance.

St. Thomas	Traffic signals flash red-amber only at locations where late night vehicle volumes are low - 1:30 a.m. - 5:30 a.m.
Sarnia	When used, standard hours are midnight to 6:00 a.m. Used at minor intersections of an arterial street where minor street traffic is low at night. No major intersections or those with high accident experience are considered.
Sudbury	Non-traffic actuated and low volume of pedestrian and vehicular activity during the hours of 1:00 a.m. and 5:00 a.m. General rule would have less than one vehicle per cycle on side street. This system was installed at the request of Council on a trial basis in 1983. No obvious problems recorded to date with some favourable comment from public.
Thunder Bay	If intersection is of fixed time control and the approach volumes drop substantially.
Toronto (Metro)	All "night flash" operation has been terminated for reasons of safety and is being replaced by "semi-actuated" controls wherever possible.
Wallaceburg	Basically used at intersections where secondary flow is minimal after hours. Flashing operations are being phased out as mechanical controllers are replaced with microprocessors and the use of detectors so the lights are green on primary unless called by secondary traffic.
Waterloo	As system control is implemented on a region-wide basis, we are attempting to phase out the use of night flash operation although it is our intention to convert many signals to semi-actuated operation whenever warranted.
Windsor	The only location is operated on the basis of a political decision.
Hull	Low volumes on secondary roads at intersections and few accidents.
Joliette	Traffic volumes, direction of vehicles and the acceleration of traffic on the principal lane.
Jonquiere	Equipment malfunction or roadwork in the vicinity of the intersection.
Laval	Flashing Red for all directions if all approaches are of equal importance - flashing amber for the principal arterial and flashing red for the secondary road.

Montreal	Very low traffic volumes on the secondary road (less than 50 v/h) and low traffic volumes on the primary road (less than 500 v/h) between 00:00 & 06:00.
Quebec	Used when the traffic signal serves a parking area such as a shopping centre. When traffic volumes are less than those which "warrant" a traffic signal for at least 4 consecutive hours.
Rimouski	This system is used as an emergency system when the controller fails.
Saint-Laurent	For safety reasons, we have decided that flashing red-red is the best solution. Flashing amber-red not understood by the majority of drivers.
Sherbrooke	Not currently used.
Thetford Mines	Traffic density in one direction versus the other. Visibility at the intersection
Fredericton	At independent intersections where traffic volumes drop below the warrants.
Saint John	Travelling habits and traffic surveys indicate that full activation is not warranted between midnight and 7 a.m.
Halifax	84 of 89 intersections flash amber/red or red/red (if volumes are relatively equal) between 12:30 a.m. and 6:00 a.m. or if in the vicinity of shopping centres or at isolated locations on the City's outskirts, the flashing mode will start at 10:30 p.m. There are only 5 intersections that don't flash at night; 2 are 5-legged crossings and the other 3 are the signalized approaches at our rotary cycle which require traffic to stop <u>only</u> during the peak hours (at all other times, it is a "Yield-Then-Proceed" situation - so a flashing display would be redundant).
Corner Brook	Used during night-time where there is a significant reduction in traffic volume. Need is determined by field observation.
St. John's	Traffic Volumes
British Columbia	(a) Flash operation of full signals - during periods of light volumes (i.e. nighttime). (b) Also used are flashing beacons on a 24 hour basis typically limited to intersections with restricted sight distances.
Alberta	The flashing operation is used only when the signal equipment has failed and into emergency operation "Flashing Mode".

Manitoba

This operation is used only at high volume generators (e.g. at a drive-in and racetrack). Signals are in flashing mode except when these facilities are in use.

Ontario

- (a) All MTC signals are actuated therefore there is no need for flashing operation
- (b) The true meaning of the flashing amber and red at signalized intersections is not readily understood by rural drivers, thus it is causing rear-end collision and undue delay

The need for flashing operation becomes necessary only under the following conditions: a) maintenance; b) controller failure (conflict monitor); c) at new installations to provide advance warning

Quebec (Prov.)

When the through traffic is less than 40% of the volume necessary to warrant a traffic signal for a period of at least 8 consecutive hours.

New Brunswick

Substantial drop in traffic volumes. However, no figures are available.

Nova Scotia

Flashing lights not used by our Department. Some cities and towns use them after 12:00 midnight.

APPENDIX D
SUMMARY OF THE RULES OF THE ROAD
TRAFFIC CONTROL SIGNALS

Canadian
Uniform Rules of the Road

December 1982

Canadian Conference of Motor Transport Administrators

TRAFFIC CONTROL SIGNALS - GENERAL

Every driver and every pedestrian shall obey the instructions of a traffic control signal unless directed to do otherwise by a peace officer.

Alberta

No equivalent provisions but the matter is covered in the sections dealing with specific signals.

British Columbia

Section 130 - substantially complies.

Manitoba

Section 84(1) - substantially complies.

New Brunswick

Sections 117, 118 - substantially comply - make it an offence to drive off the roadway to avoid the directions.

Newfoundland

Section 127 - substantially complies.

Northwest Territories

Section 97 - substantially complies but omits the exception - pedestrian not included.

Nova Scotia

Section 83(2) - substantially complies but omits the exception.

Ontario

No equivalent provision but the matter is covered under a general penalty provision (Section 188).

Prince Edward Island

Section 151 - substantially complies.

Quebec

Section 313 - substantially complies.

Saskatchewan

Section 150 - substantially complies.

Uniform Vehicle Code

Section 11-201 - substantially complies - pedestrian not included - pedestrian control signals in Section 11-203.

Yukon Territory

No equivalent provision but the matter is covered in the sections dealing with specific signals.

TRAFFIC CONTROL SIGNALS - GREEN, AMBER, RED AT INTERSECTIONS

- (1) When a green light alone is shown at an intersection by a traffic control signal,
 - (a) the driver of a vehicle approaching the signal
 - (i) may proceed straight through the intersection or may turn left or right unless a sign at such place, prohibits either such turn,
 - (ii) shall yield the right of way to other vehicles and to pedestrians lawfully within the intersection or in an adjacent crosswalk at the time such signal is exhibited;
 - (b) a pedestrian facing the signal, subject to a traffic control signal directing him otherwise, may proceed across the roadway within a marked or unmarked crosswalk and while so proceeding has a right of way over all vehicles.
- (2) When an amber light alone is shown at an intersection by a traffic control signal,
 - (a) the driver of a vehicle approaching the signal shall stop the vehicle at a clearly marked stop line, or if none, then immediately before entering the crosswalk on the near side of the intersection, or if none, then immediately before entering the intersection unless a stop cannot be made in safety;
 - (b) a pedestrian facing the signal shall not begin to cross the roadway until a green light or walk sign is shown.
- (3) When a red light alone is shown at an intersection by a traffic control signal,
 - (a) the driver of a vehicle approaching the signal shall stop his vehicle at a clearly marked stop line, or if none, then immediately before entering the crosswalk on the near side of the intersection, or if none, then immediately before entering the intersection and shall not proceed until a traffic control signal permitting the movement of the vehicle in the intersection is shown;
 - (b) a pedestrian facing the signal shall not begin to cross the roadway until a traffic control signal permitting him to enter the roadway is shown.

Alberta

(1) Green light

Sections 107 and 157 - substantially comply subject to the following: in respect to (a) (i) there is reference to a sign "designating the turning movement permitted".

(2) Yellow

Sections 108 and 158 - substantially comply.

(3) Red light

Sections 109 and 159 - substantially comply - but with respect to right turns such turns may be made unless prohibited.

British Columbia

(1) Green light

Section 132(1) - substantially complies - but with respect to 1(a) (i) there is reference to a sign "designating the turning movement permitted".

(2) Yellow light

Section 133(1) - substantially complies but specifies the yellow subsequent to the green light - also specifies pedestrian rules and right of way when in intersection during change of light.

(3) Red light

Section 134(1) - substantially complies but with respect to right turns, such turns may be made unless prohibited - left turns permitted under certain circumstances - also specifies pedestrian rule and right of way when in intersection during change of light.

Manitoba

(1) Green light

Section 84(3) - substantially complies - identical treatment of green light alone and flashing green light.

(2) Yellow or amber light

Section 84(5) - substantially complies - also specific pedestrian rules and right of way when in intersection during change of light.

(3) Red light

Section 84(7) - substantially complies - specific pedestrian rules and right of way when in intersection when light changes.

Section 84(16) - may make right turn on red after stopping.

New Brunswick

In addition to colour designations of signal lights other descriptions are used e.g. "GO", "CAUTION", "STOP".

(1) Green light

Section 119(1) - substantially complies.

(2) Yellow light

Section 119(1) - no reference to specific stopping locations, if impossible to stop may enter - if pedestrian enters intersection on light he shall yield the right of way to all vehicles.

(3) Red light

Section 119(1) - substantially complies - right turn with caution permitted on red - pedestrian may enter intersection on red if he can do so safely and without interfering with vehicular traffic - on a red light and amber light displayed simultaneously vehicle must stop and pedestrian may enter intersection in any direction.

Newfoundland

(1) Green light

Section 127(2) substantially complies.

(2) Yellow light

Section 127(4) - substantially complies - gives pedestrians in intersection at time of light change the right of way over vehicles.

(3) Red light

Section 127(6) - substantially complies.

Northwest Territories

Sections 98 and 99

(1) Green light - substantially comply.

(2) Yellow light - substantially comply (Section 100).

(3) Red light - substantially comply - right turn permitted on red after stopping yielding right of way to all other traffic (Section 101).

Nova Scotia

Section 83(2)

(1) Green light - substantially complies.

(2) Yellow light - substantially complies.

(3) Red light - substantially complies - right turn with caution permitted on red light.

Ontario

Section 124

(1) Green light - substantially complies.

- (2) Amber light - substantially complies.
- (3) Red light - substantially complies - right turn and left turn from one-way into one-way permitted after full stop - permissible turns at signal lights subject to right of way to pedestrians and other traffic lawfully within the intersection.

Prince Edward Island

Section 152

- (1) Green light - substantially complies.
- (2) Yellow light - substantially complies - pedestrians in intersection at time of light change given right of way over vehicles in the intersection.
- (3) Red light - substantially complies.

Quebec

Sections 331 and 441

- (1) Green light - substantially comply - pedestrians in intersection given the right of way.
- (2) Amber light - Section 329 - substantially complies.
- (3) Red light - Section 327 - substantially complies.

Saskatchewan

Section 150(1)

- (1) Green light - substantially complies.
- (2) Yellow light - substantially complies.
- (3) Red light - substantially complies - right turn on red permitted after full stop.

Uniform Vehicle Code

Section 11-202 - substantially complies.

Yukon Territory

Sections 183 and 228(1)

- (1) Green light - substantially comply.

Sections 184(1) and 229(1)

- (2) Yellow light - substantially comply.

Sections 185(1) and 230(1)

- (3) Red light - substantially comply - right turn on red permitted after yielding right of way to pedestrians and vehicles in intersection.

FLASHING RED, AMBER AT INTERSECTIONS

- (1) When a flashing red light is shown at an intersection by a traffic control signal,
 - (a) the driver of a vehicle approaching the intersection and facing the light shall
 - (i) stop the vehicle at a clearly marked stop line, or if none, then immediately before entering the crosswalk on the near side of the intersection, or if none, then immediately before entering the intersection;
 - (ii) having stopped, shall yield the right of way to traffic within the intersection or within an adjacent crosswalk and proceed with caution;
 - (b) a pedestrian facing the light may proceed across the roadway within a marked or unmarked crosswalk with caution.
- (2) When an amber flashing light is shown at an intersection by a traffic control signal,
 - (a) the driver of a vehicle approaching the intersection and facing the light may enter the intersection only with caution and shall yield the right of way to all traffic lawfully within the intersection and to pedestrians lawfully in an adjacent crosswalk;
 - (b) a pedestrian facing the light may proceed across the roadway within a marked or unmarked crosswalk with caution.

Alberta

Sections 108(3)(4), 159(3) and 158(3) - substantially comply.

British Columbia

Section 136(1)(2) - substantially complies.

Manitoba

Section 84(10)(12) - substantially complies - in respect to both lights the pedestrian is given right of way over all vehicles.

New Brunswick

Section 122(1)(2) - substantially complies - somewhat different approach by relating the flashing red light to a stop sign.

Newfoundland

Section 127(9)(11) - substantially complies.

Northwest Territories

Sections 102 and 103 - substantially comply.

Nova Scotia

Section 83(2)(e)(f) - substantially complies.

Ontario

Section 124(8)(9) - substantially complies - also requires a driver to yield to traffic approaching so closely as to constitute a hazard - right of way of approaching traffic is also defined.

Prince Edward Island

Section 152(8)(10) - substantially complies.

Quebec

Sections 328 and 330 - substantially comply - but refer to stop sign for stopping rule.

Saskatchewan

Section 150(3) - substantially complies - no reference to right of way - proceed when safe to do so.

Uniform Vehicle Code

Section 11-204 - substantially complies - defines procedure by reference to stop sign.

Yukon Territory

Sections 185(5), 230(4), 184(3) and 229(3) - substantially comply.

FLASHING GREEN

Alberta, British Columbia, Manitoba, Ontario, Quebec, Nova Scotia and Yukon Territory have provisions respecting flashing green lights. There is not complete uniformity among them.

Alberta

Section 107(5) - gives right of way to turn left or right or go through in relation to vehicles facing the light from across the intersection - buses of municipal bus systems can be exempted from turn prohibitions by by-law.

British Columbia

Section 136(5) - at a flashing green light at an intersection or elsewhere, the driver of a vehicle must approach the signal or intersection in a manner that he can cause the vehicle to stop and if a stop is necessary yield the right of way to pedestrians.

Manitoba

Section 84(3) - treats a flashing green light in an identical manner to a steady green light.

Ontario

Section 124(4) - driver of a vehicle approaching an intersection and facing a flashing green light may proceed through the intersection or turn left or right - subsection (13) prohibits pedestrians from entering the intersection except in accordance with the directions of pedestrian control signals.

Quebec

Section 332 - when facing a green flashing light the driver may proceed straight ahead or turn left or turn right yielding the right of way to pedestrians and other vehicles in the intersection.

Nova Scotia

Section 83(2)(a) - treats a flashing green light in an identical manner to a steady green light.

Uniform Vehicle Code

Makes no reference to flashing green light.

Yukon Territory

Section 183(5) - whether flashing green light is advanced or delayed a driver facing such light has the right of way over approaching traffic but must yield the right of way to pedestrians.

TRAFFIC CONTROL SIGNALS - GREEN, AMBER, RED, NOT AT INTERSECTIONS

- (1) When a green light alone is shown at a place other than an intersection by a traffic control signal,
 - (b) the driver of a vehicle approaching the signal:
 - (i) may proceed to pass the signal, and
 - (ii) shall yield the right of way to any pedestrian still in the roadway or on a crosswalk in the vicinity of the signal at the time such signal is exhibited.
- (2) When an amber light alone is shown at a place other than an intersection by a traffic control signal,
 - (a) the driver of a vehicle approaching the signal shall stop the vehicle at a clearly marked stop line, or if none, then immediately before entering the crosswalk on the near side of the signal, or if none, then immediately before reaching the signal unless a stop cannot be made in safety;
 - (b) a pedestrian facing the signal shall not commence to cross the roadway until a traffic control signal permitting him to enter the roadway is shown.
- (3) When a red light alone is shown at a place other than an intersection by a traffic control signal,
 - (a) the driver of a vehicle approaching the signal shall stop the vehicle at a clearly marked stop line, or if none, then immediately before entering the crosswalk on the near side of the signal, or if none, then immediately before reaching the signal and shall not proceed until a traffic control signal permitting him to pass the signal is shown;
 - (b) a pedestrian facing the signal shall not commence to cross the roadway until a traffic control signal permitting him to enter the roadway is shown.

Alberta

Sections 107(2), 108(2), 109(3), 157(2), 158(2) and 159(2) - substantially comply except on green pedestrian prohibited crossing until red light comes on traffic control signal permitting him to cross. Also except on red a pedestrian may cross.

British Columbia

Sections 132(2), 133(2) and 134(4) - substantially comply except with respect to pedestrians - on green and amber entry only as permitted by a traffic control signal - on red pedestrian permitted to cross roadway (appears contrary to model section)

Manitoba

Section 84(4)(6) - substantially complies - pedestrian required to proceed across the roadway as quickly as possible in the direction of the signal light - driver allowed to proceed if he can pass the signal light before it turns red - pedestrian in intersection when light changes is given right of way to complete the crossing.

New Brunswick

Section 119 - same rules as for signal light at an intersection.

Newfoundland

Section 127(3)(5)(7) - substantially complies.

Northwest Territories

No equivalent provision.

Nova Scotia

No equivalent provision.

Ontario

No equivalent provision - Section 124(25) and (26) provide for designated locations other than at intersections.

Prince Edward Island

Section 152(2)(4)(6) - substantially complies.

Quebec

No equivalent provision.

Saskatchewan

Section 150(1)(b)(d)(f) - substantially complies.

Uniform Vehicle Code

No equivalent provision.

Yukon Territory

Sections 183(2), 184(2), 185(3), 228(2), 229(2) and 230(2) - substantially comply with same exceptions as noted in respect to Alberta.

TRAFFIC CONTROL SIGNALS - AMBER FLASHING, RED FLASHING, NOT AT INTERSECTIONS

- (1) When a flashing red light is shown at a place other than an intersection by a traffic control signal,
 - (a) the driver of a vehicle approaching the light
 - (i) shall stop the vehicle at a clearly marked stop line, or if none, then immediately before reaching the crosswalk on the near side of the light, or if none, then immediately before reaching the light;
 - (ii) having stopped, shall yield the right of way to all pedestrians in the roadway or in a crosswalk in the vicinity of the light and proceed with caution;
 - (b) a pedestrian facing the light may proceed across the roadway with caution.
- (2) When a flashing amber light is shown at a place other than an intersection by a traffic control signal,
 - (a) the driver of a vehicle approaching the light may pass the light only with caution and shall yield the right of way to all pedestrians in the roadway or in a crosswalk in the vicinity of the light;
 - (b) a pedestrian facing the light may proceed across the roadway with caution.

Alberta

Sections 109(5), 108(4), 158(1) and 159(4) - substantially comply.

British Columbia

Section 136(2)(4) - substantially complies.

Manitoba

Section 84(11)(13) - substantially complies.

New Brunswick

No similar provision.

Newfoundland

Section 127(10)(12) - substantially complies.

Northwest Territories

No similar provision.

Nova Scotia

No similar provision.

Ontario

No similar provision.

Prince Edward Island

Section 147 - substantially complies with (1) and (2).

Quebec

No similar provision.

Saskatchewan

No similar provision.

Uniform Vehicle Code

No similar provision.

Yukon Territory

Sections 185(5), 184(4), 230(4) and 229(4) - substantially comply.

GREEN ARROW

When a green arrow is shown alone or in conjunction with a red light at an intersection by a traffic control signal,

- (a) the driver of a vehicle approaching the intersection and facing the arrow may cautiously enter the intersection only to make the movement indicated by the arrow and shall yield the right of way to pedestrians lawfully in an adjacent crosswalk and to other traffic lawfully within the intersection;
- (b) a pedestrian facing the arrow shall not commence to cross the roadway until a traffic control signal permitting him to enter the roadway is shown.

Alberta

Sections 106(3)(4) and 157(3)(4) - substantially comply - two separate provisions 'green arrow alone' and 'green arrow with red light' - in latter case driver must enter intersection cautiously.

British Columbia

Section 135 - substantially complies.

Manitoba

Section 84(9) - substantially complies.

New Brunswick

Section 119(e) - substantially complies.

Newfoundland

Section 127(8) - substantially complies.

Northwest Territories

No equivalent provision.

Nova Scotia

Section 83(2)(d) - substantially complies - rule on green arrow is a proviso on the red light rule.

Ontario

Section 124(10)(11)(12) - substantially complies - also includes provision for green arrow alone.

Prince Edward Island

Section 152(7) - substantially complies.

Quebec

Sections 333 and 440 - substantially comply.

Saskatchewan

Section 150(1)(g)(h) - substantially complies - two separate sections 'green arrow alone' and 'green arrow with red' - pedestrian may cross with green arrow alone - the section also refers to multiple arrows in the traffic signal.

Uniform Vehicle Code

Section 11-202 - substantially complies - no pedestrian rules.

Yukon Territory

Sections 183(3)(4) and 228(3)(4) - substantially comply - similar provision to Alberta.

TRAFFIC CONTROL SIGNALS - GREEN ARROW WITH RED LIGHT

(This situation is dealt with in preceding section.)

When a green arrow and a red light are shown at the same time at an intersection by a traffic control signal,

- (a) the driver of a vehicle approaching the intersection and facing the signal may enter the intersection and make only the movement indicated by the green arrow;
- (b) the driver of the vehicle shall yield the right of way to other vehicles and to pedestrians lawfully within the intersection or an adjacent crosswalk at the time the signal is exhibited;
- (c) pedestrians facing the signal shall not enter the roadway until a green light alone is exhibited subject to special pedestrian control signal indicating that they may proceed.

Alberta

Section 129 - substantially complies but omits (c).

Saskatchewan

Section 142 - substantially complies.

Yukon Territory

Sections 183 and 188 - substantially comply.

No other provinces or Northwest Territories or Uniform Vehicle Code have a similar provision.

